



Vibratory Tumbling Machine

Final Design Review

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ABSTRACT

The purpose of this document is to highlight the overall *Vibratory Tumbling Machine* project background, objectives, concept design, final design, manufacturing, and design verification. This final design review outlines the process, creation, and testing of the chosen final design for this redesign of the vibratory tumbling machine. The FDR shows the steps the team took towards completing a CAD package and a verification prototype of the final design while adapting to COVID-19 restrictions.

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1. INTRODUCTION

This team consists of three California Polytechnic San Luis Obispo Mechanical Engineering students in partnership with Mr. Ochoa, Owner/President of C&M Topline. Mr. Ochoa presented the challenge to redesign a current product of his, the Mr. Deburr DB300. The Mr. Deburr DB300 is a vibratory tumbling machine for the purpose of deburring, finishing and polishing parts. The primary objectives for this redesign were to incorporate elements of noise suppression and portability while maintaining the machine's effectiveness and efficiency. The Final Design Report outlines the project's research, engineering specifications, objectives, timeline, final design, manufacturing, and design verification.

2. BACKGROUND

2.1 VIBRATORY TUMBLING EXPLANATION

This section discusses the different components and functions of vibratory tumbling machines. This type of machine is used for the purpose of mass finishing. Mass finishing is the simultaneous finishing of a large volume of parts [1, Gillespie]. Mass finishing can be utilized in industries ranging from manufacturing, medical devices, jewelry, ammo cleaning and much more. These machines are used to deburr, finish and polish parts. The vibratory tumbling machine that this team is redesigning, the Mr. Deburr, is categorized as a vibratory tub machine. This machine can be seen in Fig. 2.1.1. This machine differs from other categories of vibratory machines; including vibratory bowl (Fig. 2.1.2), rotary tumbling barrel (Fig. 2.1.3), high energy disc (Fig. 2.1.4) and centrifugal barrel (Fig. 2.1.5). These are just a few examples of the different categories of machines.



Figure 2.1.1 The Mr. Deburr DB600 and DB300 [2, cmtopline.com]



Figure 2.1.2 A vibratory bowl machine [2, cmtopline.com]



Figure 2.1.3 Rotary tumbling barrel machine [2, cmtopline.com]



Figure 2.1.4 High energy disc machine [3, us.rosler.com/us-en/]



Figure 2.1.5 Centrifugal barrel machine [4, giantfinishing.com]

These machines consist of different components, possibly including media, compound, a motor, vibration system, a fluid system and an enclosed chamber [5, David A.]. The media is the material that is loaded into the chamber and performs work onto the inserted parts. The media comes in different shapes, sizes and materials. An example of media is shown in Fig. 2.1.6. More in depth coverage of the different medias and their purposes are covered in Section 2.3, Technical Research.



Figure 2.1.6 Ceramic media used in mass finishing [2, cmtopline.com]

The enclosed chamber comes in many different shapes and sizes and are typically how the machines are categorized as seen above in Figs. 2.1.1-2.1.5. The chamber is isolated from the rest of the machine and left free to vibrate using springs. The compound is a specially formulated solution of chemicals that is added to water to aid the finishing process. Benefits of the compound include part/media lubricity, media glaze prevention and the prevention of oxidation during finishing [6, Vibratory Mass Finishing Process]. The compound is recirculated into the chamber through the fluid system. The fluid system consists of the compound, a pump, a reservoir, piping and a delivery system. The compound can be misted onto the media and parts or dripped. Each system has a different form of fluid delivery. The vibration system of these machines typically has a motor that is connected to a shaft with eccentric weights. This shaft with eccentric weights is physically attached to the isolated chamber using bearings and causes the systems vibration. An example of the current Mr. Deburr bearing system with shaft and eccentric weights is shown in Fig. 2.1.7. An in-depth explanation of how the eccentric weights cause a vibration is covered in Section 2.1.3, Technical Research.



Figure 2.1.7 Complete shaft assembly with bearings and eccentric weights [2, cmtopline.com]

2.2 SPONSOR/END-USER INTERVIEWS

C&M Topline's Mr. Deburr is the company's flagship product yet has not received a design update in over 30 years. The Mr. Deburr comes in two sizes, 3 cu. feet (DB300) and 6 cu. feet (DB600). While the two products are relatively similar, this project's scope focuses on the 3 cu. foot Mr. Deburr. This smaller version is utilized more frequently by hobbyists whose feedback over noise and portability are of greater weight than those in the manufacturing industry [7, Ochoa]. The current design requires a bolted connection to a concrete slab, eliminating portability entirely. Mr. Ochoa has noted that because these machines and patents have existed for so long, the intellectual property has expired. This guides Mr. Ochoa in developing a list of requirements for the redesigned machine. He has left the team two competitor's vibratory machines to inspect and retrofit. One machine is currently functional while the other is stripped of its mechanical components. The stripped machine closely matches his vision of a redesign. It incorporates a complete enclosure and a visually pleasing design. A list of requirements from Mr. Ochoa is compiled in Table 2.2.1.

Table 2.2.1 Customer requirements

Noise suppression
Portable
Detailed shaft assembly analysis
Affordable to manufacture
~ 3 cu. Foot chamber
Ease of usage
Part commonality
Minimize vibration transfer

The part commonality correlates to the fluid system currently found on the Mr. Deburr DB300. He has requested to utilize this current system. The motor is another part that would ideally be utilized in the new design unless analysis supports a different, comparably priced motor. Mr. Ochoa has supplied the team with all detailed drawings, bill of materials and CAD packages for the Mr. Deburr products. He has also identified his close competitors; Burr King, Giant Finishing and Northern Tooling. Each company offers a different take on the same principle machine. These machines can have more bells and whistles while others are sold at a cheaper price with a shorter lifetime. Mr. Ochoa requests a machine that is simple to manufacture, simple to use, provides quality performance and achieves a long lifetime. A selling point of the Mr. Deburr is that it is manufactured in the United States. With the simplicity aspect of a design, almost all parts are kept in stock and are available for replacement.

Mr. Ochoa requests the follow deliverables: a complete CAD package incorporating his design requirements, manufacturing ready drawings, supporting design analysis and a demonstration prototype. Expectations for a demonstration prototype are still being expanded upon with Mr. Ochoa. Current options are to retrofit the current machines that he has provided or completely manufacture the new design.

2.3 TECHNICAL RESEARCH

The behavior of vibratory tumbling machines relies heavily on the operator. Depending on the machine that they are using, they can control the following variables: media type, media volume, compound, wet or dry process, volume flow rate of compound, volume of parts, motor rpm, machine frequency and processing time [8, Sofronas]. Each user must fine tune the process for their desired output.

For this project, the team is not analyzing the optimum conditions for each operating scenario. The team is focused on identifying motor rpm, machine frequencies and dynamic loads. The team proposes to understand these variables and maintain their effects with the new design.

The supplied mechanical work by vibration allows for the rough grained media to cut away at the surface and burrs of parts in the machine. While the media can be compared to sandpaper or a file in the manual operation of finishing and deburring a part, this is not the correct resemblance. In fact, most of the deburr and surface finishing is caused by the direct impacts of the media and the part [9, Yabuki]. This is one reason why the efficiency of a machine is correlated with higher frequencies. The maximum impact force and frequency of impact occurrence is greater in dry operating conditions [9, Yabuki]. A larger media size correlates with greater impact forces and better deburring/finishing, but the media size is governed by part size and features. It is advised to fill the chamber with sufficient media no less than 5 inches from the top edge, otherwise the vibratory motion is reduced [2, cmtopline.com].

From a variety of technical papers, the vibratory tumbling machines operate between 1500-2000 vibrations per minute [3, us.rosler.com/us-en/].

2.4 PRODUCT RESEARCH

During product research, the group found products with similar functions as the Mr. Deburr and compared their functionality to that of the Mr. Deburr. The groups goal in product research was to find products that had potential features that could be useful to include in the design of the new Mr. Deburr.

The products that are featured in this report are those deemed the greatest competition to the Mr. Deburr based on advising from our sponsor, functionality and sizing.

2.4.1 HUTSON VIBRATORY TUMBLING MACHINE

The Hutson Vibratory Tumbling machine is the one that the group was donated by our sponsor to take apart for a better understanding of the function of deburring machines. Important features include wheels for portability, in comparison to the Mr. Deburr which is bolted to the ground. It has a sound limiting lid, in comparison to the rubber flap that comes with the Mr. Deburr. This is a potential solution to the Mr. Deburr's noise complaints. The Hutson also has a more compact shape, with the shell housing containing the whole machine. On the following page, Figs. 2.4.1 and 2.4.2 are images that the group took of the donated machines [7, Ochoa].



Figure 2.4.1 Hutson vibratory tank



Figure 2.4.2 Hutson vibratory tank top view

2.4.2 GIANT FINISHING VIBRATORY TUB SERIES

The Giant Finishing Vibratory Tub Series have a variable speed motor. This allows for varying vibration speeds. It can range from very aggressive to more gentle action for more fragile parts and finishes. The eccentric weights on the shaft are also adjustable. Allowing for even more variation in vibration finishes. The Tub series prides itself on having a low working height, a vibration process timer, and coil spring type suspension [4, giantfinishing.com].

The Giant Finishing Tub also has similar features to the Mr. Deburr such as a plug type discharge door, 90 durometer polyurethane lining, curved/rounded rear tub wall, and liquid lubricant/drainage system. Fig. 2.4.3 is an example image of a Giant Finishing Tub.



Figure 2.4.3 Giant finishing tub series [4, giantfinishing.com]

2.4.3 ROYSON 3c TUMBLING MACHINE

The Royson 3c tumbling machine is a compact deburring machine that is ideal for work cell deburring. The Royson 3c has wheels allowing for increased ease of portability. The Royson 3c can also be set up with tub dividers to compartmentalize parts that are being deburred. It has a polyurethane tub liner, variable speed drive, and heavy steel construction. It also has a sound abatement cover, as pictured in Fig. 2.4.4 below, for decreased noise in the workspace [10, royson.com].



Figure 2.4.4 Royson 3c tumbling machine [10, royson.com]

2.4.4 BURR KING VIBRATORY TUMBLING MACHINE

The Burr King Vibratory Tumbling tubs are versatile because of the range of sizes that they come in. Their volumetric size can range from 2.5 – 8.5 cubic feet. They are meant to deliver high performance deburred and polished finishes. They also have an optional process timer that allows for precise timing control. The Burr King prides itself on its high-quality magnetic starter contactors [11, burrking.com]. Fig. 2.4.5 is a side view of the 4.5 cubic foot Burr King Vibratory Tumbler.



Figure 2.4.5 Burr King vibratory tumbling machine [11, burrking.com]

2.4.5 ALMCO VB-SERIES BATCH VIBRATORY TUBS

The Almco VB-Series Batch Vibratory Tubs are similar to the Mr. Deburr in their versatility. They are meant for batch type processes of parts, and they can use a wide variety of medias and compounds to find the finish the user is looking for. It comes in two standard sizes, 2.5 and 5 cubic feet. It has both wet and dry process capabilities, and it comes standard with a sound deadening enclosure as pictured in Fig. 2.4.6. Some optional features are a variable frequency drive, flowmeters for compound measurement, and an air operated tub discharge door [12, almco.com].

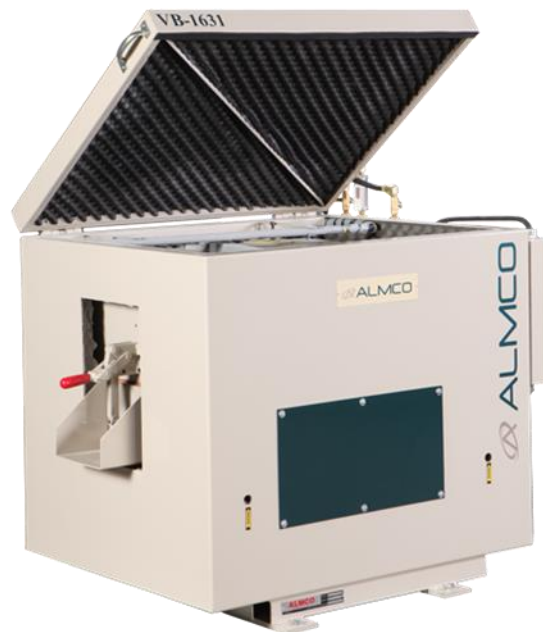


Figure 2.4.6 Almco VB-Series Batch Vibratory Tubs [12, almco.com]

2.5 Relevant Patents

The relevant patents regarding vibratory tumbling machines and deburring machines are found in Table A.1. Table A.1 is a table including each patent number, patent description, and image (if available) of the described machine. Key words used in Google Patent search to find these products were ‘vibratory tumbling machine’ and ‘deburring tumbler’.

3. OBJECTIVES

3.1 PROBLEM DEFINITION

C&M Topline's current product, a 3 cubic-foot vibratory tumbling machine, allows manufacturing companies and machinists to deburr and finish metallic parts, but has not been re-designed in over 30 years. C&M Topline requests a redesign of this machine to match and improve on competitor's features including noise reduction, increased portability, and to satisfy customer's feedback.

3.2 BOUNDARY DIAGRAM

The boundary diagram below, Fig. 3.2.1, is a representation of the scope of the project and the goals that the team aim to achieve. The boundary is drawn around the items that the team has control over, the outside items the team does not have control over. The team has control over the entire vibratory tumbling machine. This includes the inner components of the machine such as the shaft, offset weights, and springs. It is up to the team to decide the best configuration and setup of the inside components. The outside variables that the team cannot control include the machine operator, the size of the parts, the material type of the parts, the bucket, and the pump. The machine operator is not under control of the team because the machine is sold to and used by a variety of different operators. Each operator can use the machine for different parts so the team does not have control over the material or part types going into the machine.

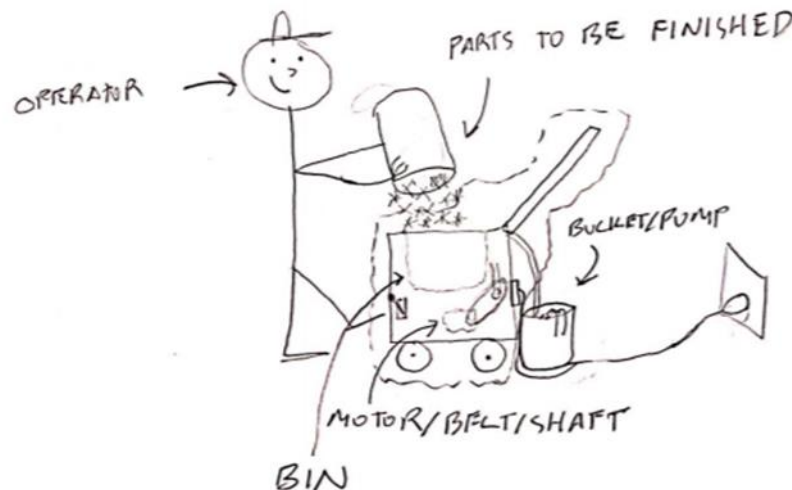


Figure 3.2.1 Boundary diagram

3.3 QUALITY FUNCTION DEPLOYMENT

The Quality Function Deployment, or QFD, is a way of listing out the customer requirements, wants, and needs that are to be incorporated in the design. The purpose is to develop engineering specifications and

tests to address the customer wants and needs. The “House of Quality” shown in Appendix B is designed to help the team determine the most important engineering specifications and needs for the project.

For the project, the most important wants and needs are noise, portability, functionality, easy to operate and maintain, and cost efficiency. These requirements were found to be the most important for the design through the use of the QFD. These customer requirements are the most important to the team for designing and testing the product so that the sponsor’s expectations are met.

Table 4.1 below is a list of the specifications and target goals for the project from the QFD. Each specification has an acceptable target goal that the team would like to achieve. Each specification also has a tolerance, risk, and compliance that is associated with them. The tolerance is how close the team would like to come to achieve the specification. The risk is the estimated difficulty the team may have in achieving each specification. The compliance is the type of way the team is to go about measuring if each specification is achieved or not.

Table 4.1 Engineering Specifications Table

Spec #	Specification Description	Specification	Tolerance	Risk	Compliance
1	Noise	< 65 dB	Max	H	A, T
2	Portability	Pass	Max	L	T
3	Hourly Power Consumed	.75 kWh	Max	H	A, T
4	Natural Frequency	TBD	TBD	TBD	TBD
5	Motor Sized for RPM	TBD	TBD	TBD	TBD
6	Cost Efficient Bearings	< \$100 each	Max	M	A, T, I
7	Reuse Current Fluid System	Pass	Max	L	S
8	Operator Setup Time	15 min	Max	L	T
9	Deburr Parts	No Part Burrs	Max	L	I, T
10	Ease of Maintenance	1 Hour	Max	L	T
11	Chamber Volume	3 Cubic Feet	Max	M	A, I
12	Manufacturing Cost Approx.	< \$1500 for 20	Max	H	T, I, S
13	Total Load (Media + Parts)	250 lbs	Max	L	T, I
14	Vibration Transfer to Floor	Pass	Min	L	T, I
15	Dynamic Loading	TBD	TBD	TBD	TBD

Risk: L = Low
M = Medium
H = High

Compliance: A = Analysis
T = Test
I = Inspection
S = Similarity

Specification in detail:

1. Noise is a very important specification that Mr. Ochoa wants to be addressed. Mr. Ochoa did not give an exact noise requirement, just that the new design needed to be lowered for hobbyists using the machine in their homes. For this specification the team had been given an estimate of lower than 65 dBs would be acceptable.
2. Portability is another very important specification for Mr. Ochoa. The current design requires the machine to be bolted into the ground, which is not desirable for many

reasons. Mr. Ochoa would like the new design to be portable, meaning that it can easily be moved around from place to place.

3. Hourly power consumed is a specification that the team decided would be a good specification to address. If the new design is more energy efficient, it would give customers a better incentive to purchasing the new machine because it would save money. An acceptable target is .75 kwh.
4. For this specification the team is going to analyze the natural frequency in order to maintain the effectiveness and efficiency of the new machine. It is still undetermined what the target natural frequency is until benchmark testing is completed. The team might achieve this specification by adding adjustable weights to the shaft in order to optimize the vibration for different sized parts
5. The motor sized for RPM is a specification the team has determined would be helpful to test if the motor was sized correctly for the required RPM.
6. Cost efficiency is an important specification for Mr. Ochoa. He would like to lower the cost for the new machine and the bearings are currently very expensive. The team has decided the under \$100 per bearings is a good target goal.
7. Mr. Ochoa has told the team to reuse the same fluid system for the new design
8. The new machine has to be easy to operate. The team has estimated that a setup time of around 15 minutes is the goal.
9. The machine must still be able to deburr parts effectively. Meaning how well the machine can deburr, finish, and polish parts must match or improve the quality as the old design.
10. Ease of Maintenance is a goal for the team and the acceptable target is around 1 hour to clean and maintain the machine.
11. The chamber volume for the tub of the machine to be around 3 cubic feet.
12. The approximate manufacturing cost is an important specification for Mr. Ochoa. He would like the manufacturing cost for the new machine to be approximately less than \$1,500 for a batch of twenty machines.
13. The total load (media + parts), meaning the total weight of the parts and the media that can be loaded into the tub, is maxed at 250 lbs.
14. Mr. Ochoa requests that the new design minimize the vibrations that the machine transfers to the floor. This is to limit the machines interactions with possible precision machines around it. The team aims to have close to no transfer of vibration to the floor
15. Similar to the natural frequency and motor RPM, the dynamic loading produced by the bearing and shaft assembly is to be analyzed and maintained in the new design. The amplitude and forces produced in the chamber are direct correlations to these variables. Mr. Ochoa suggests design elements that can produce different interactions between the media and parts within the chamber.

The high-risk specifications of the project are the noise, hourly power consumed and manufacturing cost. These specifications come from the components that are used to build the machine. The manufacturing cost directly relies on the parts like the shaft, offset weights, motor, and bearings. The hourly power consumed is related to the motor chosen and the efficiency of vibrations of the machine. In order to achieve the cost and the hourly power consumed the parts need to be cheaper and less material which could lead to part failure or a drop in the quality of the finished products which are both unacceptable results. The noise specification is a combination of the parts used and how the team goes about suppressing the noise. It is high risk since 65 dB is quiet and significantly quieter than the current design so it may be difficult to achieve.

4. CONCEPT DESIGN

4.1 IDEA GENERATION & SELECTION

The team began by identifying functions that the design needed to perform. The team found four total functions that were portability, tub noise suppression, base noise suppression, and finishing mechanism. Once these four functions were solidified, the team brainstormed any and all ideas to achieve the functions through an informal discussion with no limitations. These ideas are found in Appendix D.

Following the generation of ideas, Pugh matrices are utilized with each function to score the different ideas. The Pugh matrix compares all ideas at once along with the existing design. The Pugh matrices can be found in Appendix E. The result of the Pugh matrices outlined the promising ideas and are implemented in concepts.

With the top ideas in mind, the following figures outline idea sketches and concept builds. Figure 4.1.1 shows the intended structural components of the new design. Figure 4.1.2 shows the top ideas for the machine's portability. Figure 4.1.3 shows various noise suppression techniques for the machine. Figure 4.1.4 shows a concept build for the functionality of a lid.

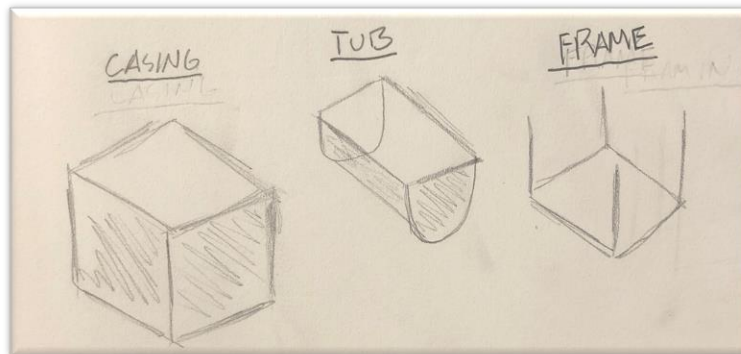


Figure 4.1.1 Structural housing sketches

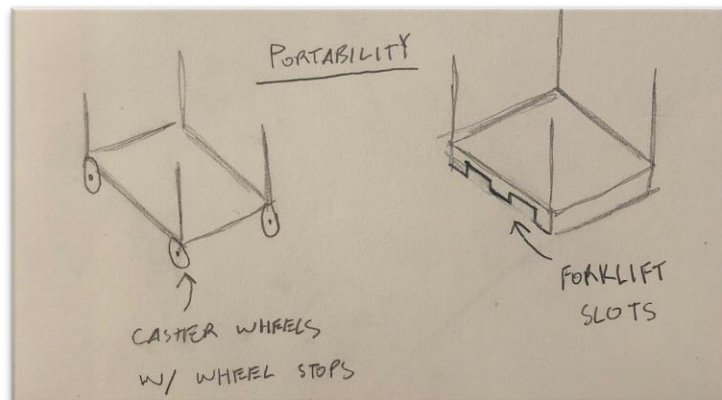


Figure 4.1.2 Portability concept sketches

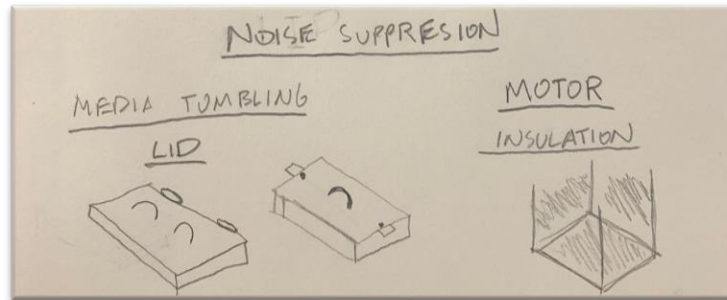


Figure 4.1.3 Noise suppression sketches



Figure 4.1.4 Concept lid build

From the top ideas and concepts, a single concept needed to appear. While the ideas presented represent only a function, they needed to be incorporated into a single design choice. The function solutions are now combined into different build configurations. These build configurations are then scored utilizing the weighted matrix seen in Fig. 4.1.5 below.

Factors:	Noise Suppression	Portability	Energy Efficient	Detailed Analysis	Cost Efficient	Part Commonality	Easy to Operate	Functionality	Ease of Maintenance	Sliding	Vibration Dampening	
Weights:	5	5	2	2	4	4	3	4	4	2	3	
Concepts												
ABD	5	5	3	3	4	4	5	5	5	4	5	
ABE	4	5	3	3	4	4	5	5	5	4	5	
ABF	5	5	3	4	4	4	5	5	4	4	5	
ABG	3	5	3	3	4	4	5	3	5	3	5	
ABH	5	5	3	3	4	4	5	5	5	4	5	
ACD	5	4	3	3	4	4	5	5	5	3	5	
ACE	4	4	3	3	4	4	5	5	5	3	5	
ACF	5	4	3	4	4	4	5	5	4	3	5	
ACG	3	4	3	3	4	4	5	3	5	3	5	
ACH	5	4	3	3	4	4	5	5	5	3	5	
ABD	25	25	15	15	20	20	25	25	25	20	25	TOTAL
ABE	20	25	15	15	20	20	25	25	25	20	25	240
ABF	25	25	15	20	20	20	25	25	20	20	25	235
ABG	15	25	15	15	20	20	25	15	25	15	25	240
ABH	25	25	15	15	20	20	25	25	25	20	25	240
ACD	25	20	15	15	20	20	25	25	25	15	25	230
ACE	20	20	15	15	20	20	25	25	25	15	25	225
ACF	25	20	15	20	20	20	25	25	20	15	25	230
ACG	15	20	15	15	20	20	25	15	25	15	25	210
ACH	25	20	15	15	20	20	25	25	25	15	25	230

Figure 5.1.5 Weighted decision matrix

Key		
A	Vibratory Tub	
B	Caster Wheels	
C	Caster Wheels and Forklift Slots	
D	Insulate Motor	
E	Soundproof Panels	
F	Encase Motor	
G	Hinged Lid	
H	Screw On Sealed Lid	

Figure 4.1.6 Weighted decision matrix key

From this weighted design matrix, three concepts emerged as the top result. The first result was the vibratory tub design, caster wheels, and insulate the motor. The second result was the vibratory tub design, caster wheels, and soundproof panels. The third result was the vibratory tub design, caster wheels, and the screw on sealed lid. The team used a combination of all three results in choosing the preliminary design of the machine.

Caster wheels have been selected for this design. The housing design allows customers the flexibility to also permanently bolt the machine to the floor if required. The customer could also be given the choice between caster wheels, glides or no portability options when purchasing the machine. The caster wheels provide a proven reliable and effective solution to portability. Previous competitor's design showcases the caster wheels ability to keep the machine from running and tipping over while it is operated. The wheels will also raise the machine off the floor and therefore reduce the vibration transferring to the floor. Certain caster wheels can also be selected to incorporate shock absorption.

When the team visited Injectors Direct, a local San Luis Obispo company producing fuel injectors, we noticed that the vibratory bowl machine (Figure 2.1.2) produced noise from two areas, the tub and the motor. The machine had a screw on lid that secured it to the tub and isolated a great deal of noise. However, the motor and its open exposure to environment still produced much noise. A screw on lid system will be incorporated in the new design. As of the moment, we anticipate that it will have polyurethane on the inside and sheet metal on the outside, replicating the tubs material design. The lid will have an ergonomic handle or two. For the remaining base, sound proof paneling will be placed on a wall of the sheet metal casing to dampen noise produced by the motor. The new housing has less open

exposure and should help to reduce the noise levels. The team is exploring options to encase the motor itself but are worried about rising heat levels.

A single housing for the machine has been chosen. This satisfies a risk identified from the previous design due to exposed high speed shafts and pinch points. Mr. Ochoa has also suggested that a singular housing would be ideal for the redesign. This shape provides visual appeal through its symmetry. With the vertical support springs near the top of the housing and the tub resting within the housing, the center of gravity is much lower and allows for the machine to be mounted on caster wheels.

While there are several ways to transfer energy to the tub to produce vibrations, the team has chosen to stay with the shaft and eccentric weights to produce mechanical vibration. This method provides a reliable and cost-efficient solution that has been an industry standard for decades. Other solutions would significantly increase the manufacturing cost above \$1,500. This also aids in part commonality between the existing Mr. Deburr DB300.

4.2 CONCEPT CAD AND PROTOTYPE

Each of the function solutions listed above are heavily reliant on the structural support and housing of the design. Figure 4.2.6 shows an isometric view of the CAD and Figure 4.2.7 shows a bottom isometric view. This new design plans to utilize the tub already in production by C&M Topline. The new design will incorporate vertical support springs to allow the tub to rest inside the housing. The support framing design will allow customers to still have the option to bolt the machine to the floor if needed. A plate is seen in Figure 4.2.7 to illustrate the location of a single caster wheel.

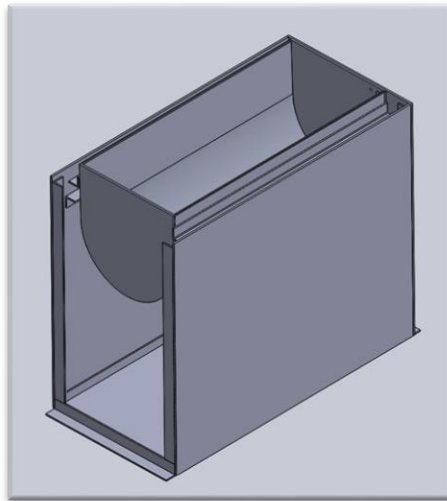


Figure 4.2.6 Concept CAD view one

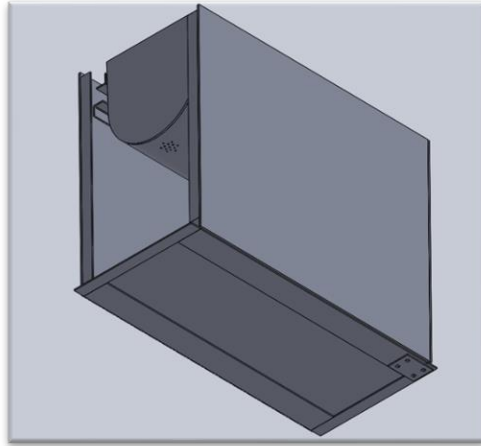


Figure 4.2.7 Concept CAD view two

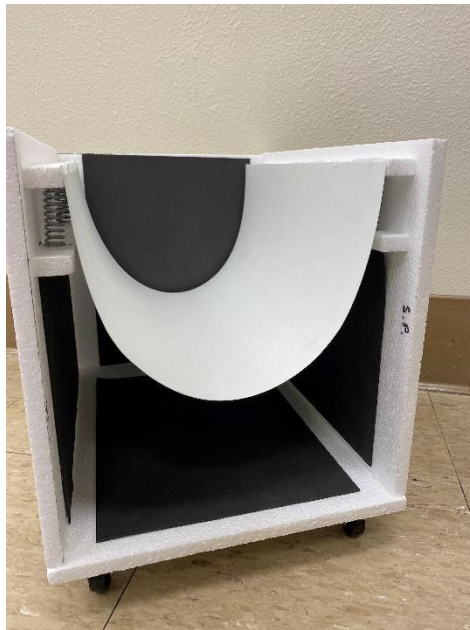


Figure 4.2.8 Concept prototype

4.3 MOVING FORWARD

The CAD and concept prototype represent only the initial components. The components that will be incorporated next for visual aid are the lid with attachment points, caster wheels, soundproof paneling and a maintenance door. The motor location and how to attach the shaft bearings to the tub are to be analyzed further and then incorporated. Several design details will have to be discussed with Mr. Ochoa moving forward in the next phase of detailed design.

The current challenges the team recognizes are providing analysis for noise reduction excluding physical testing, utilizing the ADAMS software to understand dynamic loads and manufacturing of a structural and functioning prototype. There are a few design hazards the team is monitoring and exploring options to

increase the safety of the machine which can be seen in Appendix G. A major hazard of this design is that the media and parts can be tumbled while exposed which can lead to a hazard if someone put their hand into the machine while running. A few ways to minimize this risk is to develop safety training or a safety manual for users in order to educate them in the proper use of this machine. Another design hazard is when the machine is turned on, the motor, belt, and shaft rotating pose a significant safety hazard. A way to eliminate this risk is to create a safety lock feature that locks the motor so that it cannot be turned on while the maintenance door is open. In addition to that safety feature, the motor and belt must be properly housed, and the power supply must be grounded so there is no concern of electrocution. The last design hazard the team has is the possibility of the machine tipping over due to the height of it and the vibration it emits. The team can prevent this by putting the machine on caster wheels to make it more stable and provide analysis in the future that the machine cannot fall over during use.

Despite current struggles with using the ADAMS software to model the current design. The team moved forward with the completion of hand calculations to determine the dynamic load on the bearings. We are currently struggling with a way to determine the tension in the belt, and how to create a spreadsheet that does the calculation with the weights in different areas. The schematic for this calculation can be found in Appendix F.

5. FINAL DESIGN

5.1 Overall System

The final design is broken down into four subsystems. The overall design is shown in Figures 5.1.1 and 5.1.2.

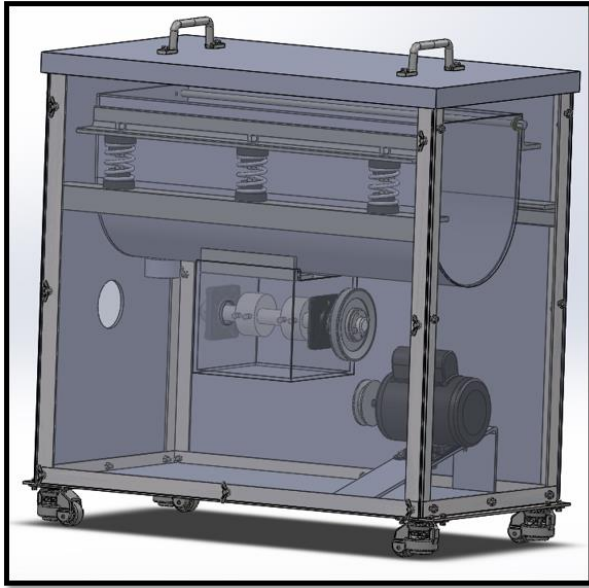


Figure 5.1.1 Inside components

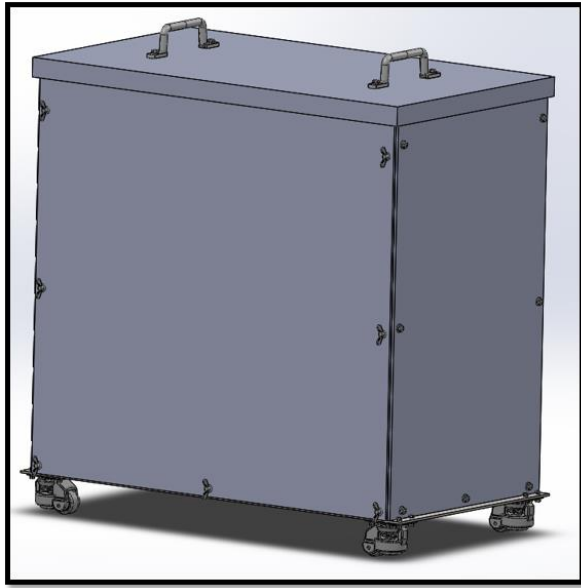


Figure 5.1.2 Overall assembly

The four subsystems are the base assembly, fluid system, vibration system, and the tub assembly. The subsystems work together to create the vibratory tumbling machine. First, the base assembly provides the structure and support for the entire machine. The tub assembly provides the housing and support for the media and parts. The vibration system creates the necessary vibration to vibrate the tub and in turn tumble the media and parts. The fluid system provides lubrication for the media and parts. Each subsystem is described in further detail in the next sections.

5.2 Base Assembly

The main function of the base assembly is to provide the structure and support for the machine. The base assembly and what components it is made out of is shown in Figure 5.2.1 below. The base assembly includes the lid that provides the seal for sound suppression. Also included in the base assembly is the addition of acoustic foam paneling around the five panels of the walls and on the lid. The base assembly is made up of right-angle steel and steel plates that are welded and bolted together. On the front side of the machine shown clearly in Figure 5.1.2, the panel is connected to the right-angle steel by butterfly screws. This allows the front panel to be easily removed to be used as a maintenance door. This maintenance door will allow maintenance to be performed on the machine. Also, four leveler caster wheels are bolted to the bottom plate. These caster wheels allow the machine to be portable and minimize the vibration transfer from the machine to the floor.

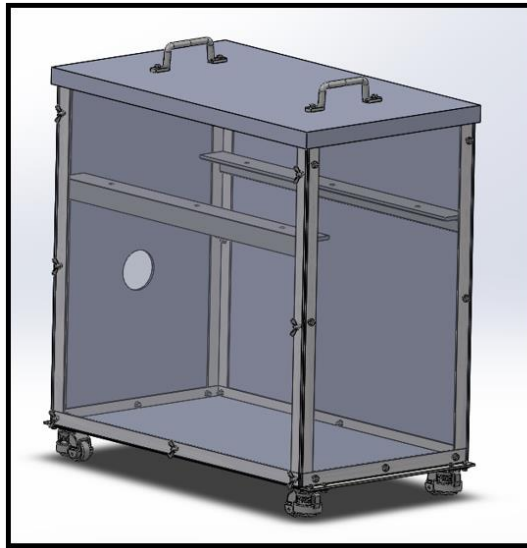


Figure 5.2.1 Base Assembly

5.3 Fluid Assembly

The main function of the fluid system is to provide lubrication to the media and the parts. The fluid system is made up of the pump, the pump tub, the spray pipe and valve, the rubber piping. The full assembly is shown below in figure 5.3.1. The fluid system is connected to the outside via the hole that can be seen in Figure 5.2.1 above. Connected to that hole is the pump tub which holds the fluid compound and the pump. The pump is connected to the rubber piping that feeds up through the spray pipe to release the fluid onto the media and parts. There is a drain feature on the tub itself that is connected to the same pump tub via more rubber piping.

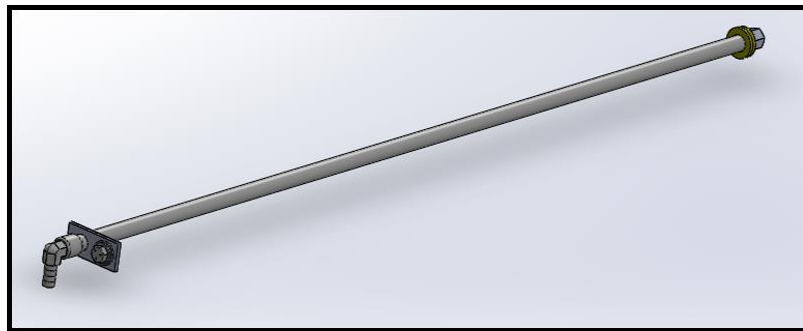


Figure 5.3.1 Fluid Assembly

5.4 Tub Assembly

The main function of the tub assembly is to house the media and parts that will be tumbled and deburred. The tub assembly is made up of the tub itself, the railings, and the drainpipe. The full assembly is shown below in figure 5.4.1. The tub assembly is attached to the base assembly via the springs. The springs are attached to the railings on the tub. The springs keep the vibration isolated to just the tub assembly and away from the rest of the machine. The tub assembly has a drainpipe that is attached to the fluid system by rubber piping that removes the fluid from the tub and back into the pump tub.

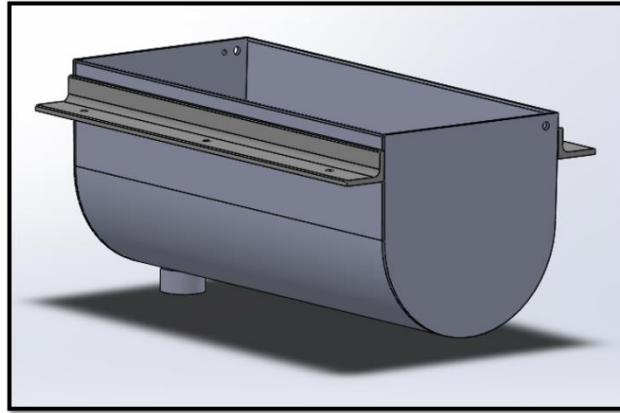


Figure 5.4.1 Tub Assembly

5.5 Vibration Assembly

The main function of the vibration assembly is to create the vibrations necessary to tumble the parts. The vibration assembly is made up of the bearings, the springs, the shaft, the offset shaft weights, the motor and belt. The components of the assembly are shown below in figure 5.5.1. The vibrations are created first by the motor which is a 0.75 HP motor. The motor is connected to a pulley that is connected to the shaft via bushings. The motor rotates at 3450 RPM which rotates the shaft and the offset weights. Due to the weights being offset on the shaft, it causes the shaft to deflect. The shaft is connected to the tub and the deflection is what causes the vibrations that tumbles the media and in turn deburrs the parts.

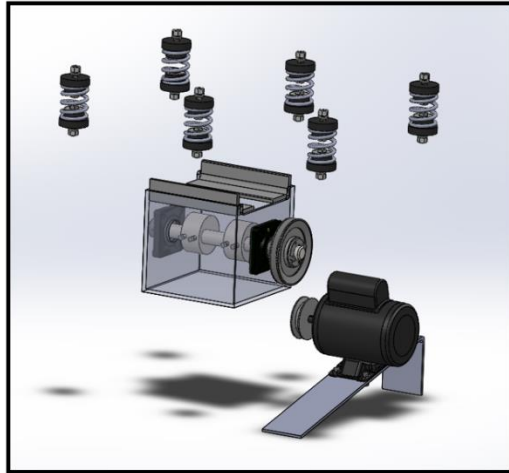


Figure 5.5.1 Vibration Assembly

5.6 Design Justification

The justification for this design is based off of hand calculations, previous designs, Finite Element Analysis programs, and prototypes tests. One part of the design verification plan was the structural prototype the team created. The goal of the structural prototype was to confirm that the design choices we made actually achieved the goals of the project. Originally the design of the machine had a motor housing that would be lined with soundproof paneling to reduce the noise of the motor. The team was worried about the heat that would be produced from the motor, so this is why we chose this as the structural prototype. The two goals we tested this motor housing for was noise suppression and then a heat test to make sure the temperature did not rise too much. The structural prototype was a smaller version of the motor housing. It was a box that we lined with a variety of different thicknesses and shapes of soundproof paneling and then tested the noise and the temperature when a heat source was placed inside. The team found that the pyramid shaped foam that was 1.5 inches thick was the best choice based on the fact that it achieved a 12 dB reduction with a minimal thickness and cost. Other combinations of sound paneling achieved a greater dB reduction but at a much higher cost and the team made the judgement that the pyramid shape alone would be better to get the manufacturing cost down. The heat test performed found that the rise in temperature was too much to have a motor housing, so the design was modified to remove the motor housing and have the sound paneling cover the surface area of the entire interior of the machine. This will provide a lot more surface area for the heat from the motor to dissipate while providing the same sound reduction. Some of the hand calculations done were the spring force calculation, temperature rise calculation, and stress analysis of the structure. The spring force calculation found that using 6 springs in the design, the force seen by those springs would be 315 lbf. The springs used are rated for 495 lbf so there is no chance of failure or fatigue of the springs. The temperature rise calculation is based off of an enclosed surface with a heat source. In the case of this design the heat source is the motor which gives off around 200 watts of heat. Based on the surface area of the enclosure, the temperature rise of the enclosure is 22.5 °F [13]. The max ambient temperature the motor is able to run at without cutting down on its lifetime is 104 °F. This temperature rise comes close to hitting the max temperature of the motor and will be accounted for. This is something that the team will test and go into more detail in the Design Verification Plan. The next calculation done was a stress analysis of the structure. The buckling critical stress was found to be 24 ksi which based on the yield strength of low

carbon steel gives a factor of safety of 2.2. The max critical stress was found to be 2.94 ksi which gives a factor of safety of 18.2. The stress was also analyzed using Abaqus which is an FEA modeling software. The max stress was found to be 1.11 ksi and the max displacement was found to be 0.011 inches which matches up with the hand calculations and proves the design will not fail.

5.7 Safety, Maintenance, and Repair

The design of the machine is very safe, there are not a lot of hazards to the machine. The tumbling of the media and parts do not move with a lot of force and are safe enough to place your hand in the tub while moving. The rotation of the shaft and weights will not be an issue because it will be encased inside the machine and covered by panels. The old machine does emit a lot of noise which is going to be minimized by the inclusion of the sound paneling. With the inclusion of the leveler caster wheels the machine is safe from tipping over because it will be flat on the floor when in use and will only be on wheels when being moved around. The motor does have a chance of overheating in the design which is why the team has a plan that will be discussed in the Design Verification Plan later on in the report. For maintenance and repair on the machine, as previously talked about in section 5.2, one panel of the base assembly has butterfly screws so the panel can be easily removed. This will act as a maintenance door because maintenance and repair does not need to happen on this machine often. All internal parts of the machine will be accessible from this panel and any maintenance or repairs can be performed from it.

5.8 Cost Analysis Breakdown

The breakdown for the cost analysis of our final prototype can be found in Appendix M along with the Bill of Materials. Due to the part commonality of the design, the majority of our parts came directly from our sponsor, Daniel. Due to the adaptive manufacturing for our verification prototype, there were a few extra parts that the group needed to purchase from Home Depot and Ace Hardware.

5.9 Design Changes

As will be discussed in the next chapter, the verification prototype deviated from the CAD due to part availability. This factor along with the delayed manufacturing completion causes the team to implement no design changes to the base CAD. The team has many design recommendations that are influenced by the outcome of manufacturing that will also be discussed later.

6. Manufacturing

6.1 Procurement

For the verification prototype, the team went through Daniel to purchase parts to complete the prototype as well as reusing and repurposing parts from old tumbling machines provided to the team by the sponsor Daniel Ochoa. The breakdown of the parts purchased and used is broken up into the different subsystems which can be seen in Appendix M. The parts highlighted in green are parts that are being purchased by Daniel/the team. Most of these parts will be purchased as raw material that is cut to size. This includes all the steel and sheet metal that needs to be cut to size, the leveler caster wheels, bolts, washers, and screws needed. The sound paneling is the only part that comes from a separate company which is Foam N' More.

6.2 Adaptive Manufacturing

The beginning of our manufacturing required many design changes based upon the parts that we were working with. The main difference revolved around recycling the tub from a previous machine rather than one from our design. This tub had different dimensions for the length, width, and height. This caused a domino effect for many parts that we already had dimensioned. We utilized a binder with all our drawings and made changes directly to that to track our changes. We also decided to change the tolerance of some holes based on predicted clearance and fit. Various smaller design changes occurred due to manufacturing capabilities. This included the placement of the vertical angle steel inside of the base frame. Our biggest challenge was making sure that our changes did not affect interactions with parts down the road. This led to us taking a manufacturing approach of finalizing parts right before they needed to be assembled so that we could verify dimensions in real life. Based on this tub, the fluid system could not be easily implemented within the quarter's time frame.

6.3 Part Production

The manufacturing of the parts needed for the verification prototype are broken down by subsystem starting with the Base Assembly. Figure 6.3.1 below shows the components of the base assembly.

Base Assembly		
		Caster Wheels
		Sound Paneling
	Frame Structure	
		Bottom Frame A
		Bottom Frame B&D
		Bottom Frame C
		Vertical Frame A
		Vertical Frame B
		Vertical Frame C
		Vertical Frame D
		Spring Rail A&B
	Sheet Metal	
		Side Plate A&C
		Side Plate B
		Side Plate D
		Bottom Plate
	Lid Assembly	
		Lid
		Handle
		Sound Paneling

Figure 6.3.1 Base Assembly Components

The caster wheels and handle are parts that are purchased and not manufactured. The rest of the parts listed in Figure 6.2.1 are manufactured out of purchased raw material. The sound paneling is cut to size using a table saw and using a mill for holes. It is then cut into 5 pieces for each side of the base assembly. Two pieces are cut into 35 in by 37 in pieces for Side Plate A&C. The piece for Side Plate B is cut into a 35 in by 21.25 in piece with a hole that is cut using a mill. The piece for Side Plate D is cut into a 35 in by 21.25 in piece. The piece for the Bottom Plate is cut into a 36.5 in by 20.9 in piece. The sound paneling for the lid is cut into a 36.5 in by 20.9 in piece as well. Moving on to the frame structure, the components are Bottom Frame A, B, C, D, Vertical Frame A, B, C, and D. These components made out of right-angle steel bars are cut to size using the abrasive saw.



Figure 6.3.2 Using the abrasive saw to cut angle steel to size

A drill press is used to create holes in Vertical Frame A, D, and Bottom Frame A. The dimensions can be seen in the respective drawings for each piece in Appendix N.



Figure 6.3.3 Drill presses used to press holes in angle steel

The lid is made out of sheet metal and cut using a water jet cutter. The four sides will be bent into right angles using a sheet metal brake and joined together with fillet MIG welds. The four holes are cut using a mill. The dimensions can be seen in the Lid drawing in Appendix N. Side Plates A, B, C, D and Bottom Plate are made out of sheet metal and cut to size/holes added using a water jet cutter. The dimensions can be seen in the respective drawings in Appendix N. The next subsystem with manufacturing is the Tub Assembly shown in Figure 6.3.2 below.

Tub Assembly		
		Tub Shell
		Drain Pipe
		End Plate A
		End Plate B
		Spring Rail C&D

Figure 6.3.2 Tub Assembly Components

As seen by the coloring mentioned previously, the only components manufactured are the Spring Rail C&D. Spring Rail C&D are made out of right-angle steel bars and cut to size using the abrasive saw. The dimensions can be seen in the respective drawing in Appendix N. The next subsystem with manufacturing is the Vibration Assembly shown below in Figure 6.3.5.

Vibration Assembly	
Spring Assembly	
	Spring
	Plastic Holder
Motor Components	
	0.75 HP Motor
	Base Plate
	Pulley
	Belt
Shaft-Bearing Components	
	Split Tapered Bushing Bore Pulley
	Bushing
	Eccentric Mass
	1.25D 15.625L Shaft
	Bearings
Support Structure	
	Angle Steel
	Bearing Box

Figure 6.3.5 Vibration Assembly Components

As seen by the coloring mentioned previously, the components manufactured are the Base Plate, Angle Steel, and the Bearing Box. The Base Plate is created out of angle steel and will be cut to size using a water jet cutter. The Angle Steel piece is made out of right-angle steel bar and cut to size using a water jet. The dimension can be seen in the respective drawing in the Appendix N. The Bearing Box is made from sheet metal and will be cut for welding by the water jet cutter.

The tub is already manufactured and has an unwanted hole in the side of it. To fix this a piece of acrylic will be cut to size and using an adhesive it will be fixed to the hole. This will stop the media and the ceramic material from exiting the machine

6.4 Assembly

The assembly instruction is broken down into a step by step numbered process. This process includes all the parts manufactured by the team and purchased.

1. Building the frame structure (Refer to Drawing Frame Assy in Appendix N for orientation of bars)
 - a. MIG weld the end of Bottom Frame A to the ends of Bottom Frame B&D
 - b. MIG weld the end of Bottom Frame C to the welded frames in the previous step to create a rectangle
 - c. MIG weld Vertical Frames A, B, C, D to the inside corners of the structure created in the previous step
 - d. MIG weld the Spring Rail A to Vertical Frames A and D at a height of 24.75 from the bottom of the Vertical Frames
 - e. Repeat step d. on the other side of the structure with Spring Rail B, Vertical Frames B and C respectively



Figure 6.4.1 Welding together frame

2. Using the m6 bolts, nuts, and washers attach each level caster wheel to the bottom frame structure using the 3 holes located on each corner
3. Place the Bottom plate on the inside of the bottom of the frame structure (resting on the railings of Bottom Frame A and C) and using a stitch pattern, MIG weld the plate to all 4 sides of the frame structure
4. Attach the soundproof paneling to the Bottom Frame using the soundproof adhesive
5. MIG Weld the Base Plate onto the Bottom Frame according to the drawings
6. Attach the motor to the base plate using the 5 16 hex bolt, locknut, and washers.
7. Attach the Split Tapered Bushing Bore Pulley onto the shaft of the motor.
8. MIG weld the End Plate A and End Plate B to the tub.
9. MIG weld the Drain Pipe to the tub on the hole
10. MIG weld the Spring Rail A&B to the sides of the tub in the orientation of the drawing
11. Assemble the six springs according to the Mr. Deburr Spring Assembly Drawing
12. Attach the six springs onto the underside of the tub via Spring Rail and on top of the other Spring Rails that are attached to the frame
13. Put the shaft through the two sides of the Bearing Box with holes and feed the 2 eccentric weights in the middle onto the shaft and use the set screws to keep them in place
14. MIG weld the rest of the sheet metal plates together to create the Bearing Box
15. MIG weld the 2 angle bars onto the top of the Bearing Box
16. Attach the bearings to the shaft sticking through the holes
17. Attach the Bushing to one side of the bearing box
18. MIG weld the Bearing Box in the middle of the tub via the angle bars
19. Attach the Bushing to the Split Tapered Bushing Bore Pulley using the V-belt
20. Attach the soundproof paneling to the Side Plates A, B, C, and D using the soundproof adhesive
21. Connect the Side Plates A, B, C, and D to the respective Vertical Frames and Bottom Frame pieces using the 5/16 hex bolts, locknut, and washers.
 - a. Side Plate A should be connected using the 5/16 Butterfly Bolts
22. Assemble the Fluid Assembly according to the Mr. Deburr Pipe Assembly drawing
23. The Pipe Assembly will attach to the tub through the dedicated holes and be fastened.

24. Flexible tubing will connect from the barbed hose connector to the pump on the outside of the machine.
25. Flexible tubing will also attach to the drainpipe and exit to the fluid reservoir.
26. Create the lid by bending the 4 sides together using a sheet metal break and then MIG weld the 4 corners together
27. Attach the soundproof paneling on the bottom using the soundproof adhesive
28. Attach the two lid handles using the 5/16 hex bolt, locknut, and washers
29. Place the lid on top of the overall assembled machine

6.5 Final Prototype

Below are photos of the final prototype. The front and side panels are removed for visual clarity and simply bolted on to the frame. The prototype was able to function as intended in limited capacity due to an undersized motor. The behavior of the tumbling media produced similar results to that of the previous Mr. Deburr DB300.



Figure 6.5.1 Final assembly first look



Figure 6.5.2 Final assembly with lid

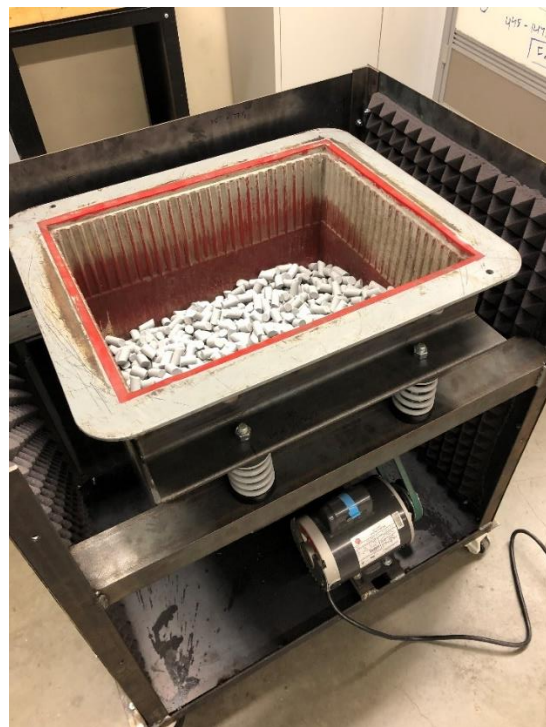


Figure 6.5.1 Final assembly with partial media loaded

7. Design Verification

The Design Verification plan was not able to be completed fully. When the verification prototype was being completed, a larger than anticipated shaft and offset weight was provided to the team. This larger shaft diameter and larger offset weight added more weight and required more power from the motor than it could handle. This in turn caused the motor to draw too much power and became overloaded based upon the heat of the motor. Luckily, the machine was able to run for around 20 seconds at a time before the breaker tripped and the machine shut off. Unfortunately, this means that the testing shown in Appendix P was not able to be completed as the machine could not be run at length with the current motor. However, by comparison of noise the team noticed a sizeable noise difference between the redesigned Mr. Deburr machine and the original Mr. Deburr machine. The team is confident that the noise reduction requirement of the system was met. The other large requirement was movability which was accomplished as the machine was able to be moved. The other requirement of reducing vibrations to the floor was accomplished as well because the machine was able to be locked from moving by the leveling casters. The main requirements sent out by our sponsor were achieved, the actual data and test results were not able to be completed. If more time were given along with no Covid-19 restrictions, the team would have been able to re-test with the correct shaft diameter and offset weights.

8. Project Management

The design process encompasses three main sections; design, build and test. Each portion roughly spans the length of a single Cal Poly academic quarter (10-12 weeks). For a breakdown of tasks and projects to be completed, see Appendix C of the team's Gantt chart. The main deliverables of the project are included in Table 8.1 below.

Table 8.1 Quarterly project timeline

DATE	DELIVERABLE
2/18/20	Concept CAD
2/25/20	Concept Prototype
3/2/20	Preliminary Design Review
4/9/20	Interim Design Review
4/16/20	Structural Prototype
4/21/20	Detailed CAD
5/4/20	Critical Design Review
6/7/20	Safety Review
6/15/20	Test Review
10/20/20	Confirmation Prototype Review
11/24/20	Final Design Review Report
11/27/20	Senior Project Expo
12/3/20	Complete Checklist

The completed milestones of the project are seen in Table 8.1 above.

When it came to a final build, we utilized our budget and the components donated to us by Daniel to construct a version of our machine that would be a suitable verification prototype. We found this solution allowed us to save money, as well as complete the tasks necessary to complete the functionality testing portion of Senior Project.

9. CONCLUSION/RECOMMENDATIONS

The purpose of this report is to encompass the completion of this project, as well as discuss our final design in detail. Upon delivery of the verification prototype and this Final Design Report, the project will be complete. Unfortunately, because of the setbacks in our timeline we were unable to complete any true testing on our verification prototype. Also, due to the adaptive manufacturing based on the alterations of critical dimensions, there were a few manufacturing errors that impacted the performance of our verification prototype.

This project focused on the redesign of an existing product for C&M Topline. Therefore, the concept generation, CAD and prototype were critical in verifying the feasibility of a new product for C&M Topline. Potential revisions that could be made moving forward would be using plastic outer casing to avoid additional noise due to rattling. Placing the motor pulley system directly under the tub's center of gravity would decrease external forces that can rotate the tub. Further work should also be completed to better implement the motor and fluid system to the structural frame.

10. REFERENCES

- [1] Gillespie, LaRoux K. *Mass Finishing Handbook*. Industrial Press, 2007.
- [2] “U.S. Manufacturer of Deburring & Vibratory Finishing Machines.” *C&M Topline*, cmtopline.com/.
- [3] GmbH, Rösler Oberflächentechnik. “Rösler - Specialist in Surface Technology.” *Rösler Mass Finishing - Shot Blasting - Consumables*, us.rosler.com/us-en/.
- [4] “Vibratory Tub Series (GT).” *Giant Finishing, Inc.*, giantfinishing.com/equipment/vibratory-finishing-equipment/vibratory-tub-series-gt/.
- [5] David A. “Vibratory Finishing: Versatile, Effective, and Reliable.” *Metal Finishing*, vol. 106, no. 5, 2008, pp. 30–34., doi:10.1016/s0026-0576(08)80123-7.
- [6] “Vibratory Mass Finishing Process.” *Metal Finishing*, vol. 97, no. 12, 1999, p. 23., doi:10.1016/s0026-0576(00)81115-0.
- [7] Ochoa, Daniel. “Senior Project Introduction Interview.” 13 Jan. 2020.
- [8] Sofronas, A., and S. Taraman. “Model Development and Optimization of Vibratory Finishing Process.” *International Journal of Production Research*, vol. 17, no. 1, 1979, pp. 23–31., doi:10.1080/00207547908919592.
- [9] Yabuki, A., et al. “Contact Forces and Mechanisms in a Vibratory Finisher.” *Wear*, vol. 252, no. 7-8, 2002, pp. 635–643., doi:10.1016/s0043-1648(02)00016-9.
- [10] “Vibratory Finisher.” *Royson Engineering Co.*, www.royson.com/vibratory-finisher/Davidson.

[11] "Burr King." *Models 25, 45 & 85 Vibra King Chambers - Product Details*,

www.burrking.com/catalog/p-100001/models-25-45-85-vibra-king-chambers.

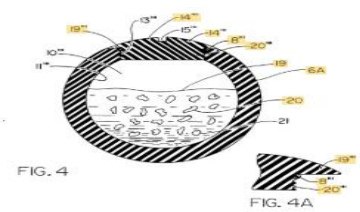
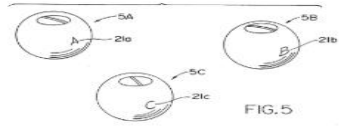
[12] "VB-Series Batch Vibratory Tubs." *Almco*, www.almco.com/index.php/equipment/vibratory

[finishing/batch-tubs/vb-series](http://www.almco.com/index.php/equipment/vibratory/finishing/batch-tubs/vb-series).

[13] "Heat Dissipation In Electrical Enclosures - Electrical References - Elliott Electric Supply". *Elliottelectric.Com*, 2020,

APPENDIX A

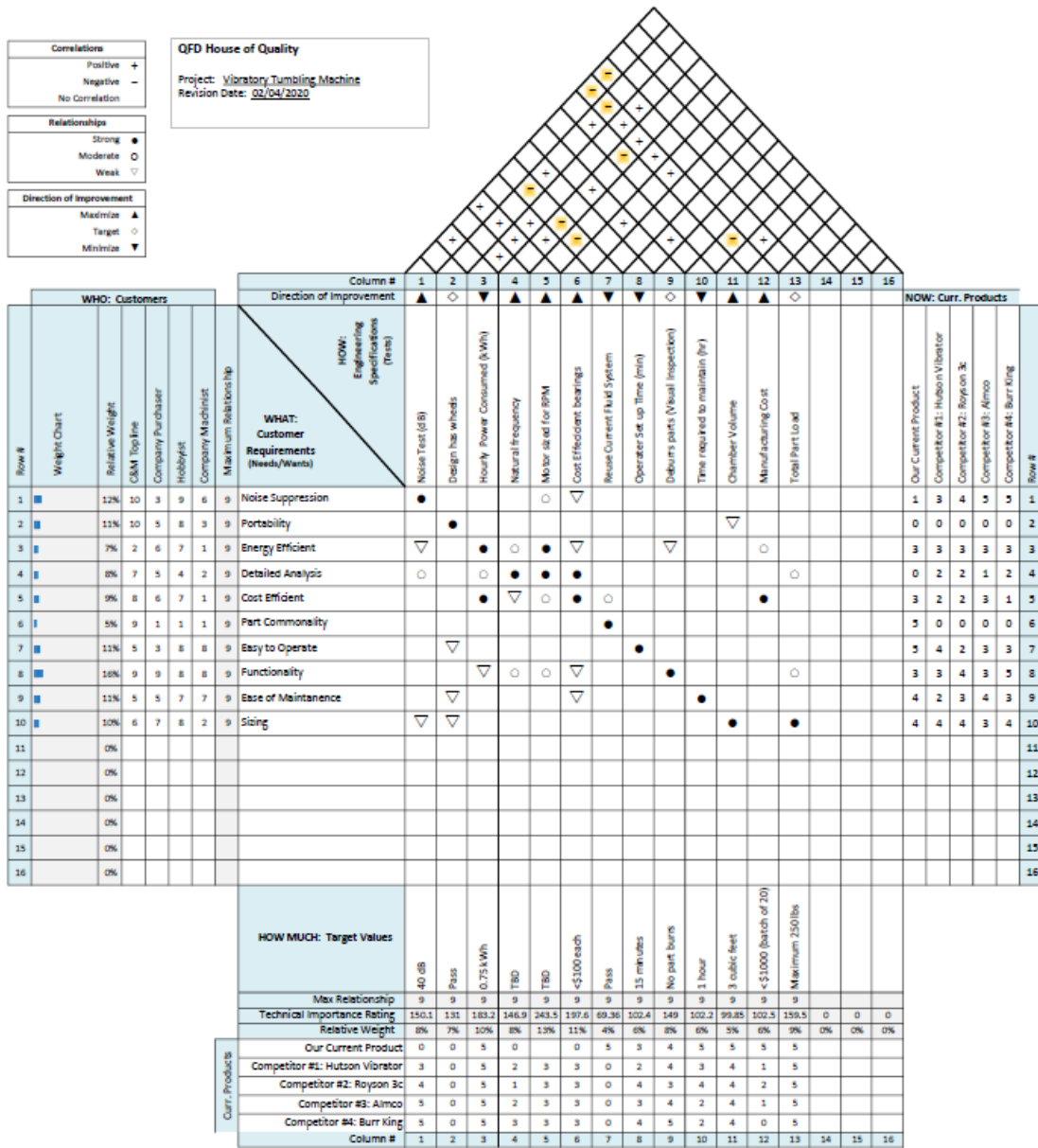
Table A.1 Initial Patent Search Findings

Patent Number	Patent Title	Description	Drawing
US5486135A	Vibratory tumbling machine vessel for burnishing or cleansing metal, plastic or ceramic elements	Accessory burnishing-treatment apparatus for treatment, namely deburring, turning corners, polishing or cleaning of elements, namely metal, plastic, or ceramic (typically glass) elements. The apparatus is a self-contained hollow sphere, preferably made from substantially abrasion-resistant plastic, that works in conjunction with typically any traditional vibratory tumbling machine.	 
CN1775475B	Vibro-tumbling machine	The present invention provides a vibro-tumbling machine (10) in particular for inner surfaces of a manufactured product (18) by means of an abrasive mix comprising several elements of not particularly hard material, abrasive particles, water and additives, the machine (10) comprises vibrating means (20,30) to cause a relative movement between the various elements of the abrasive mix and the manufactured product	N/A
JP2001018159A	Vibrating deburring device	The present invention relates to the media and put into containers attaching the workpiece to the inside, about the vibratory deburring machine deburring and polishing the workpiece by vibrating the container.	N/A

Patent Number	Patent Title	Description	Drawing
US3464163A	Vibratory finishing machine	<p>The present invention relates to a vibratory finishing machine of the type including a vibrating tub or drum containing a polishing media and in which various types of metallic and other articles or workpieces may be disposed for the purpose* of polishing, deburring or otherwise finishing such articles. More specifically, the invention relates to a vibratory finishing machine including an improved fixture for supporting a plurality of workpieces in spaced apart relation in the polishing media contained in the vibrating drum of the machine in order to effect finishing of such workpieces.</p>	
US4301625A	Bowl-type vibratory finishing machine	<p>A vibratory finishing machine has a bowl structure supported by elastomeric mounts, and a drive system for vibrating the bowl structure about a node point located along a vertical center axis of the bowl structure. Each of the elastomeric mounts has one portion secured to the bowl structure, and another portion secured to a base structure.</p>	

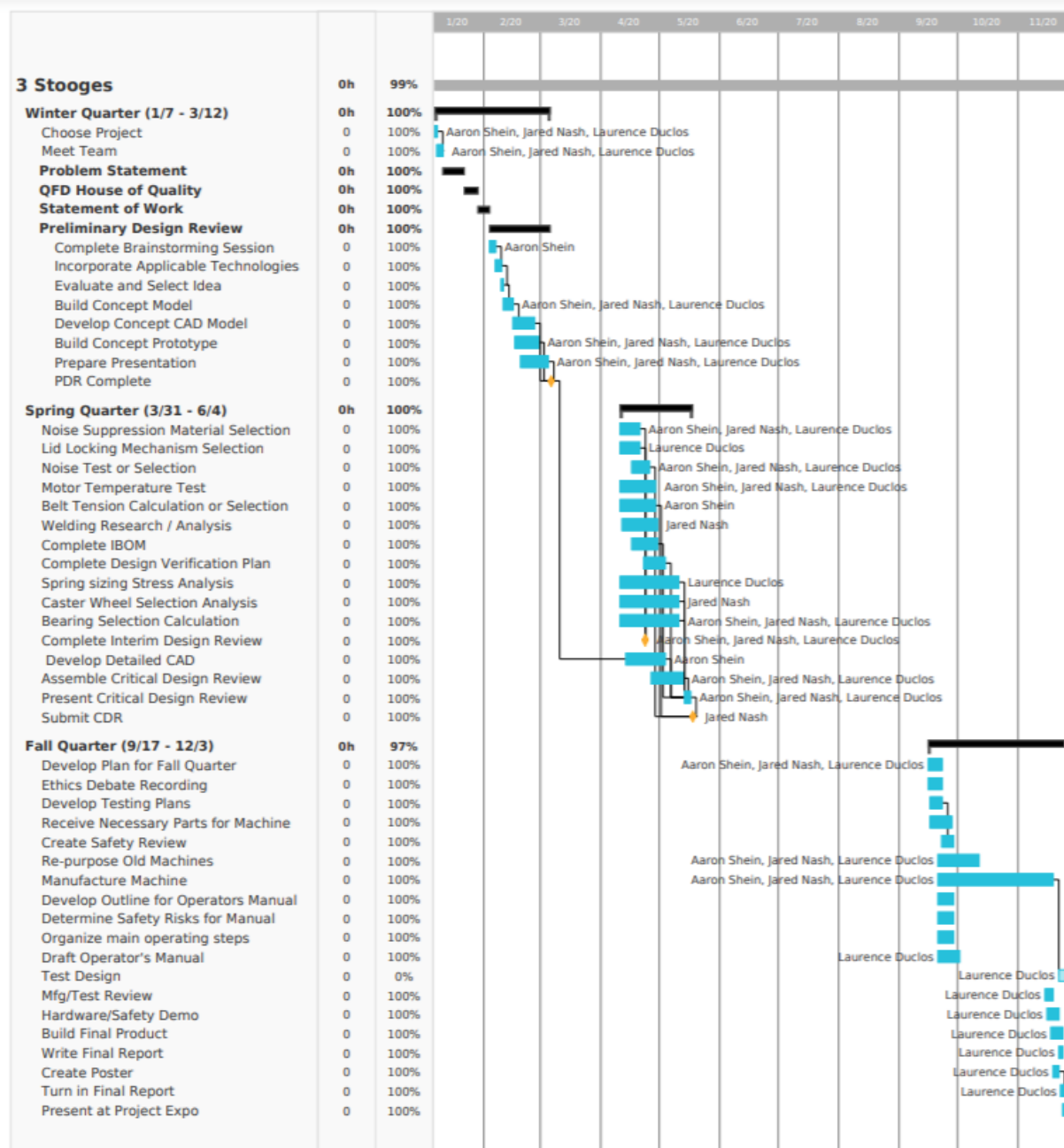
APPENDIX B

QFD House of Quality



APPENDIX C

Gantt Chart



APPENDIX D

Idea Lists

Portability	Noise Suppression Tub	Noise Suppresion Base	Finishing Mechanism
Shopping cart + lock mechanism	Hydraulic mechanism lid	Different springs (stiffness)	Vibrating tub
Furniture sliders	Garage door style lid	Insulate springs	Belt sander
Light weight machine	Less media	Foam insulation	MicroBlasting
Caster wheels (plate, bracket, socket, stem)	Wind shade roll up	Rubber insulation	Magnetic Deburring
Easy to take machine apart and build back together	Hinged lid, drops in back	Insulate motor	Manual Filing - Baseline
Forklift slots	Detachable lid	Insulate pump	
Stand so it doesn't have to be bolted to ground	Screw on lid	Rubber guards	
	Double hinged vault	Less or more springs	
	Flap (leather, rubber)	Quieter motor (less RPM)	
	Lid with rubber seal	Encase motor	
	Thicker polyurethane, less impact from media	Soundproof panels	
	Line tub with a foam	Thicker casing	
	Line tub with a rubber	Lighter weights (less vibrations)	

APPENDIX E

Decision Matrices

Pugh Matrix: Noise Suppression Tub							
Criteria	Detachable lid	Hinged lid	Screw on lid	Lid with seal	Line with foam/rubber	Flap - Baseline	Weight
Noise Suppression	1	1	1	1	1	0	-1
Cost Efficient	1	1	1	1	1	0	
Easy to Operate	0	0	0	0	0	0	
Functionality	-1	0	0	0	-1	0	
Total load (Media + Parts)	-1	-1	-1	-1	0	0	"Worse"
Ease of Maintenance	-1	0	-1	-1	0	0	0
Sizing	0	-1	0	0	-1	0	
Net Score	-1	0	0	0	0	0	
Rank	6	1	1	1	1	1	

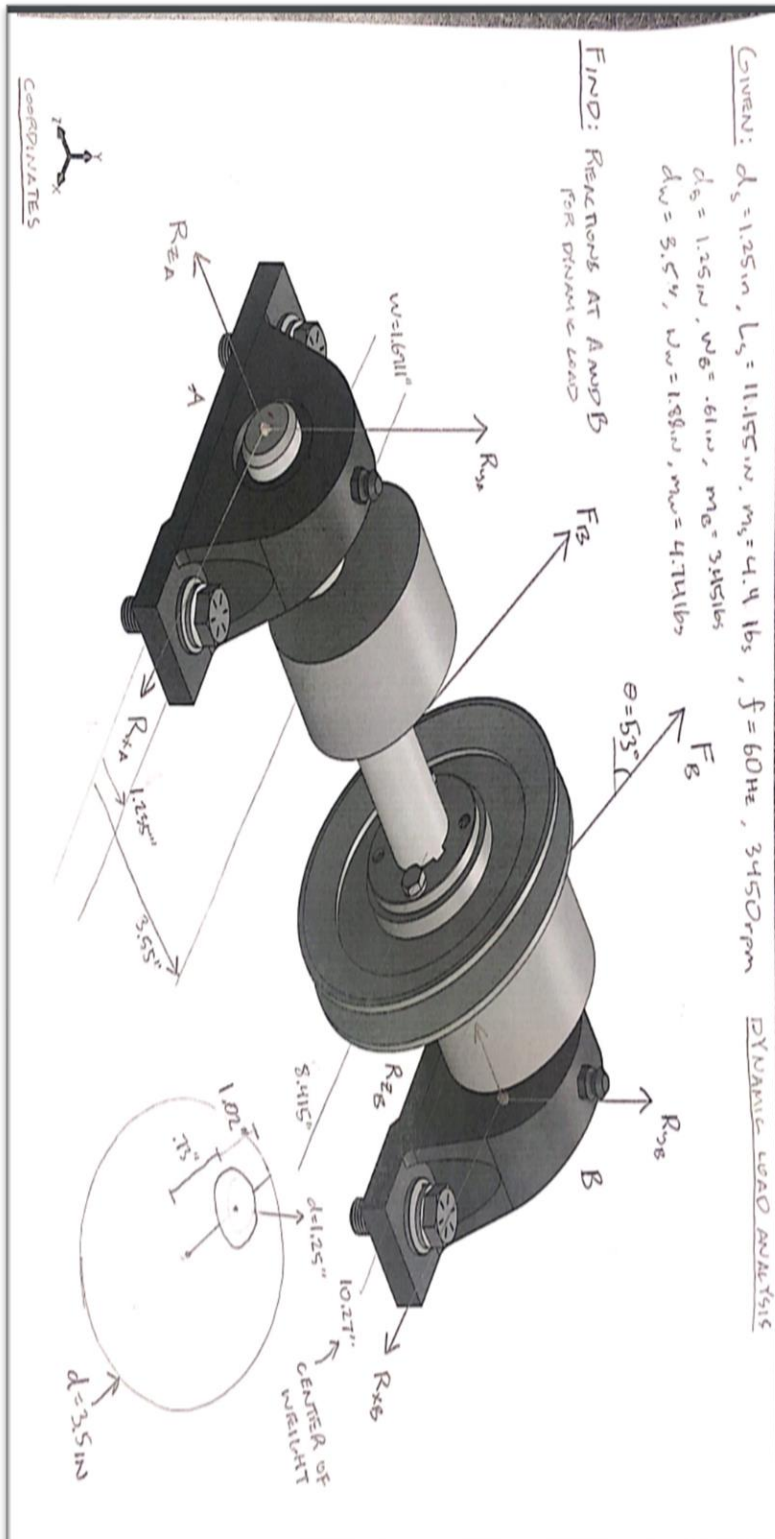
Pugh Matrix: Finishing Mechanism						
Criteria	Vibrating tub	Belt sander	Microblasting	Magnetic deburring	Manual filing - Baseline	Weight
Noise Suppression	0	0	0	0	0	-1
Portability	-1	-1	-1	-1	-1	
Energy Efficient	0	0	0	1	1	
Detailed Analysis	0	0	0	0	0	
Cost Efficient	1	-1	-1	-1	-1	0
Part Commonality	0	0	0	1	1	
Easy to Operate	1	1	-1	-1	-1	
Functionality	1	0	0	1	1	
Ease of Maintenance	0	-1	-1	-1	-1	"Neutral"
Sizing	1	0	-1	0	0	
Net Score	3	-2	-5	-1	-1	
Rank	1	4	5	2	2	

Pugh Matrix: Portability						
Criteria	Forklift slots	Caster wheels	Caster wheel + forklift slots	Glides	Baseline	Weight
Noise Suppression	0	1	1	1	0	-1
Portability	1	1	1	-1	0	
Structural Analysis	-1	-1	-1	-1	0	
Performance	0	0	0	0	0	
Sizing	-1	-1	-1	0	0	0
Vibration Dampening	0	1	1	1	0	
Net Score	-1	1	1	0	0	
Rank	5	1	1	3	3	
						"Neutral"

Pugh Matrix: Noise Suppression Base							
Criteria	Rubber guards	Insulate motor	Soundproof panels	Smaller motor	Encase motor	None - Baseline	Weight
Noise Suppression	1	1	1	1	1	0	-1
Cost Efficient	1	1	1	1	1	0	
Part Commonality	0	0	0	-1	1	0	0
Easy to Operate	0	0	0	0	0	0	"Neutral"
Functionality	0	0	0	-1	0	0	
Ease of Maintenance	0	0	0	0	-1	0	
Dynamic Loading	0	0	0	-1	0	0	
Sizing	-1	0	0	0	0	0	
Net Score	1	2	2	-1	2	0	
Rank	4	1	1	6	1	5	

APPENDIX F

Preliminary Analysis



APPENDIX G

Design Hazard Checklist

Y	N	
<input type="checkbox"/>		1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
	<input type="checkbox"/>	2. Can any part of the design undergo high accelerations/decelerations?
<input type="checkbox"/>		3. Will the system have any large moving masses or large forces?
	<input type="checkbox"/>	4. Will the system produce a projectile?
	<input type="checkbox"/>	5. Would it be possible for the system to fall under gravity creating injury?
	<input type="checkbox"/>	6. Will a user be exposed to overhanging weights as part of the design?
	<input type="checkbox"/>	7. Will the system have any sharp edges?
	<input type="checkbox"/>	8. Will any part of the electrical systems not be grounded?
<input type="checkbox"/>		9. Will there be any large batteries or electrical voltage in the system above 40 V?
	<input type="checkbox"/>	10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
	<input type="checkbox"/>	11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
	<input type="checkbox"/>	12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
	<input type="checkbox"/>	13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
<input type="checkbox"/>		14. Can the system generate high levels of noise?
	<input type="checkbox"/>	15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
<input type="checkbox"/>		16. Is it possible for the system to be used in an unsafe manner?
	<input type="checkbox"/>	17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any “Y” responses, on the reverse side add:

- (1) a complete description of the hazard,
- (2) the corrective action(s) you plan to take to protect the user, and
- (3) a date by which the planned actions will be completed.

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
<p>The tumbling of the media and metal parts creates a hazard because they are constantly moving and rotating around which could be hazardous if someone stuck their hand in the tub of the machine to retrieve parts when it was on.</p> <p>It was previously thought that the tumbling of the media and metal parts created a hazard due to the constant motion and rotation. However, upon talking to our sponsor it is safe to put your hands in the media while the machine is on because the parts do not move with a lot of force.</p>	<p>Develop user training for safe use of the machine. Safety manual for how to properly use the machine</p> <p>There is no need for corrective action for this hazard because it is no longer deemed a hazard after consultation with our sponsor Daniel Ochoa</p>	<p>3/5</p> <p>N/A</p>	<p>N/A</p>
<p>The rotation of the motor and belt along with the rotating creates a hazard for when the machine is on if someone opened the housing</p> <p>We have updated the design of our machine to no longer include a maintenance door. Instead have one of the side panels of the machine be easily removed to provide access to the internal parts of the machine</p>	<p>Create a safety lock feature where the machine's motor cannot be turned on if the housing door is open</p> <p>The safety lock feature is no longer necessary because there is not going to be a housing door. Instead, have a warning on the machine and in the manual to not operate the machine without the side panels attached and to not operate the machine while maintenance is performed. This option was deemed to be the best option for maintenance because our sponsor Daniel Ochoa told us that maintenance does not need to be performed frequently so having a maintenance door is not necessary and can instead just have one of the side panels be removeable.</p>	<p>3/5</p> <p>5/7</p>	<p>5/19</p>
<p>The motor in the machine will run at 110V</p> <p>No change in this plan</p>	<p>Properly house the motor and belt so no one can touch it while it is running and make sure the power supply is grounded</p> <p>No change in this plan. The motor is securely mounted to the base plate in the current design and the power supply is grounded as well</p>	<p>3/5</p> <p>5/7</p>	<p>5/19</p>

<p>The machine emits 85 dB which is very loud</p> <p>No change in this hazard</p>	<p>Enclose the motor in soundproofing to help quiet down the noise escaped and design a lid to seal the noise from the media and tumbling.</p> <p>This is still the planned corrective action for this hazard. The lid has been designed and will be placed on the frame of the machine to encase the entire machine and stop sound from being emitted. Different types of sound proofing material have been purchased and the planned structural prototype is to test an enclosed space with the different types of soundproofing to see the amount of noise reduced.</p>	<p>3/5</p> <p>5/7</p>	<p>5/19</p>
<p>The machine has a possibility of tipping over due to the height of it and the vibrations it emits</p> <p>No change in this hazard</p>	<p>Put the machine on caster wheels to prevent the machine from tipping by making it more stable</p> <p>The design has been updated to not just be caster wheels but caster wheels that can be adjusted to have a flat support extend out and be retracted to still maintain portability but have increased stability. These will be purchased and included in the design</p>	<p>3/5</p> <p>5/7</p>	<p>5/20</p>
<p>The motor has a chance of overheating with soundproofing material and a motor housing</p>	<p>The planned corrective action is to develop a test enclosure and test whether or not the heat produced by the motor will be too much to be enclosed in a housing. A heat transfer calculation will be done to back it up as well. If it is found that the heat is too much, the motor housing will be removed and the soundproofing material will be placed on the interior of the whole machine</p>	<p>5/7</p>	<p>5/20</p>

APPENDIX H

Structural Prototype

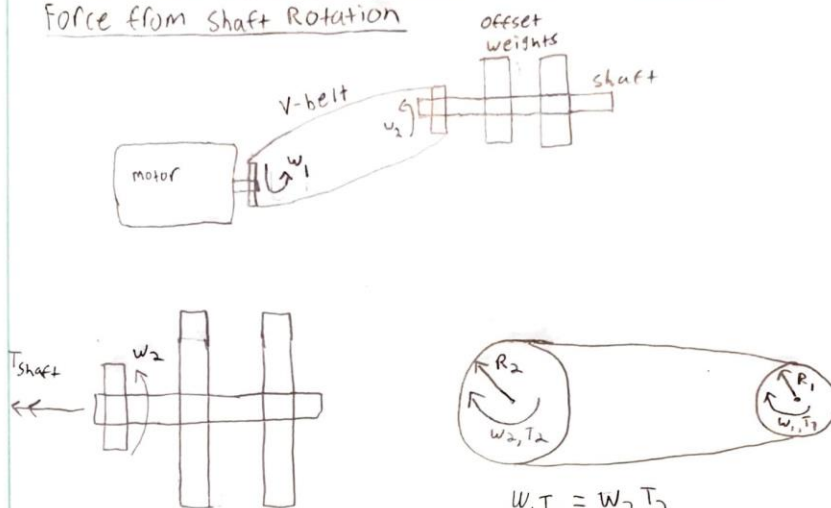


APPENDIX I

Spring Analysis

Spring Analysis

Force from Shaft Rotation



$$w_1 T_1 = w_2 T_2$$

$$T_2 = \frac{w_1}{w_2} T_1$$

Known/Given:

$$w_1 = 3450 \text{ rpm}$$

$$HP = \frac{3}{4} \text{ HP}$$

$$D_1 = 2.93 \text{ in}$$

$$D_2 = 4.7 \text{ in}$$

Find: F_{shaft} from T_2

$$w_2 = \frac{D_1}{D_2} (w_1)$$

$$w_2 = \left(\frac{2.93 \text{ in}}{4.7 \text{ in}} \right) (3450 \text{ rpm})$$

$$w_2 = 2128.72 \text{ RPM}$$

$$\frac{HP}{\text{rpm}} = \frac{550 \text{ ft} \cdot \text{lb}}{\frac{\text{ft}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{2\pi \text{ rad}}{1 \text{ rev}}} = 5252 \text{ (conversion factor)}$$

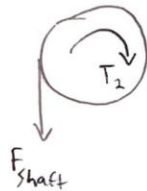
$$T_1 = \frac{5252 \text{ HP}}{\text{RPM}}$$

$$= \frac{(5252)(.75 \text{ HP})}{3450 \text{ RPM}}$$

$$T_1 = 1.14174 \text{ lb} \cdot \text{ft}$$

$$T_2 = \left(\frac{3450 \text{ rpm}}{2128.72 \text{ rpm}} \right) (1.14174 \text{ lb-ft})$$

$$T_2 = 1.85041 \text{ lb-ft}$$



$$T_2 = F_{\text{shaft}} \cdot R_2$$

$$F_{\text{shaft}} = \frac{T_2}{R_2}$$

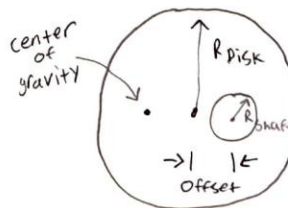
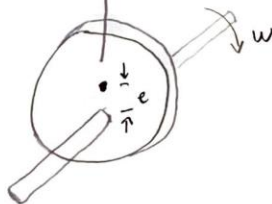
$$= \frac{1.85041 \text{ lb-ft}}{\frac{4.7 \text{ m}}{2 \times 12 \text{ in}} \text{ ft}}$$

$$F_{\text{shaft}} = 9.45 \text{ lbf}$$

Force from Offset Weight

$$F = m e \omega^2$$

\uparrow offset \uparrow weight



$$\text{Offset} = .73 \text{ in}$$

$$D_{\text{shaft}} = 1.25 \text{ in}$$

$$D_{\text{weight}} = 3.5 \text{ in}$$

$$W_{\text{weight}} = 4.41 \text{ lbf}$$

$$\omega = 2128.72 \text{ rpm}$$

$$e = \frac{\pi r_{\text{weight}}^2 \times \text{offset}}{\pi (r_{\text{weight}}^2 - r_{\text{shaft}}^2)}$$

$$e = \frac{\pi \left(\frac{3.5 \text{ in}}{2} \right)^2 \times .73 \text{ in}}{\pi \left(\left(\frac{3.5 \text{ in}}{2} \right)^2 - \left(\frac{1.25 \text{ in}}{2} \right)^2 \right)}$$

$$e = .836725 \text{ in}$$

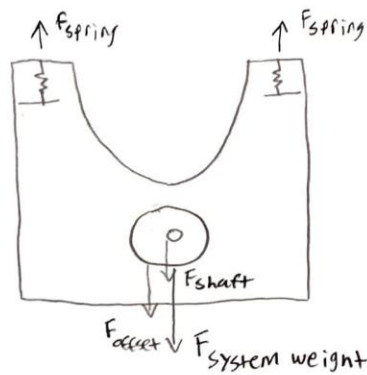
$$F_{1-\text{weight}} = \left(\frac{4.41 \text{ lbf}}{32.174 \frac{\text{ft}}{\text{s}^2}} \right) \left(\frac{.836725 \text{ in}}{12 \text{ in}} \right) \left[\left(2128.72 \text{ RPM} \right) \left(\frac{1 \text{ min}}{60 \text{ s}} \right) \left(\frac{2\pi \text{ rad}}{1 \text{ rot}} \right) \right]^2$$

$$F_{1-\text{weight}} \approx 475 \text{ lbf}$$

$$F_{\text{offset}} = 2(F_{1-\text{weight}})$$

$$F_{\text{offset}} \approx 950 \text{ lbf}$$

Total Force in spring



$$F_{\text{total}} = F_{\text{offset}} + F_{\text{shaft}} + F_{\text{system weight}}$$

$$= 950 + 9.45 + 300$$

$$F_{\text{total}} \approx 1259.45 \text{ lbf}$$

$$\text{Factor of safety} = 1.5$$

$$F_{\text{safety}} = n \times F_{\text{total}} \\ = 1889.2 \text{ lbf}$$

$$F_{\text{spring}} = \frac{F_{\text{safety}}}{6} = \frac{1889.2}{6} = 314.86 \text{ lbf}$$

$$F_{\text{spring}} = 314.86 \text{ lbf}$$

APPENDIX J

Temperature Rise Calculation

Temperature Rise

$$L = 37 \text{ in}$$

$$W = 18.5 \text{ in}$$

$$H = 35 \text{ in}$$

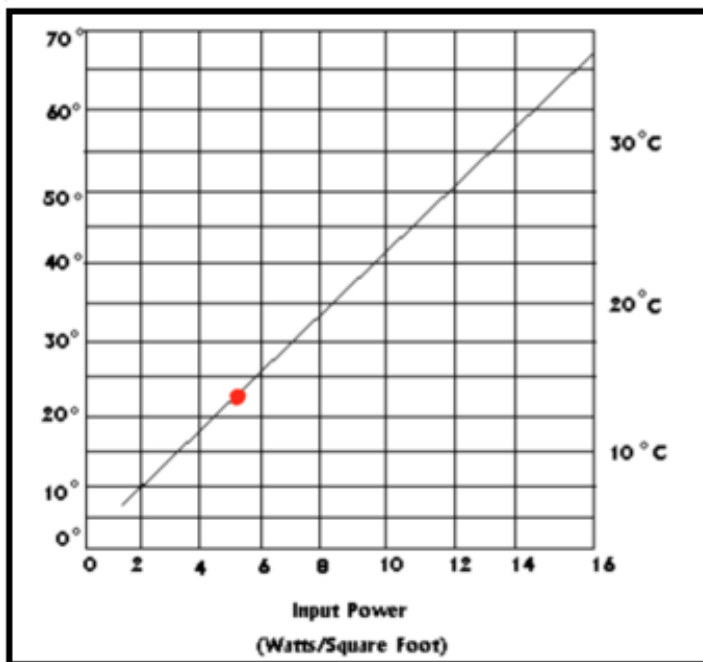
$$\text{Input Power} = 200 \text{ W}$$

$$A = 2 \left[(37)(18.5) + (18.5)(35) + (37)(35) \right] \times \frac{1 \text{ ft}^2}{144 \text{ in}^2}$$

$$A = 36.5 \text{ ft}^2$$

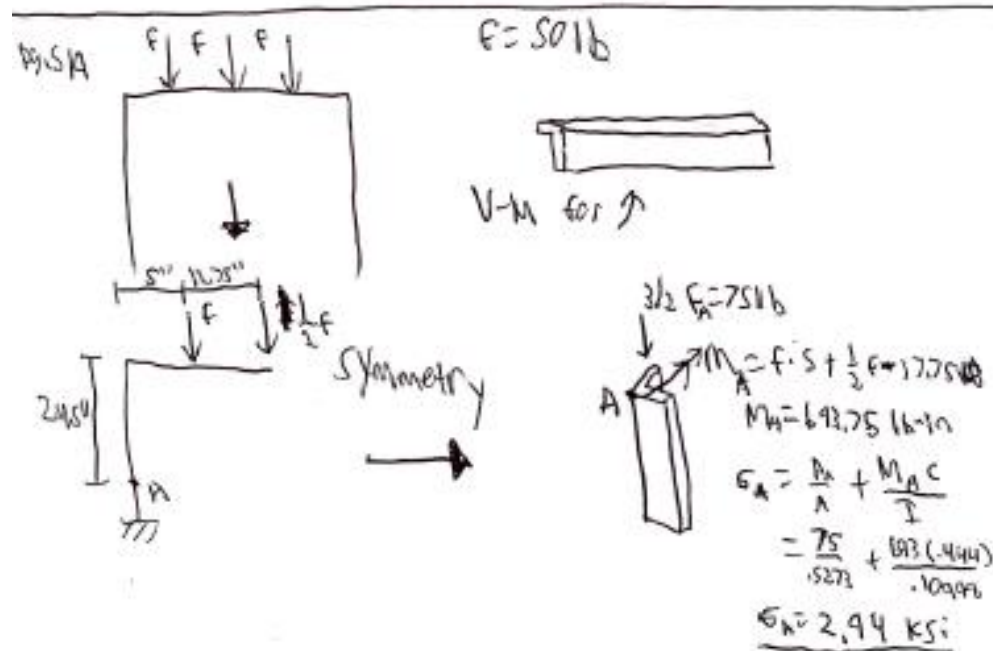
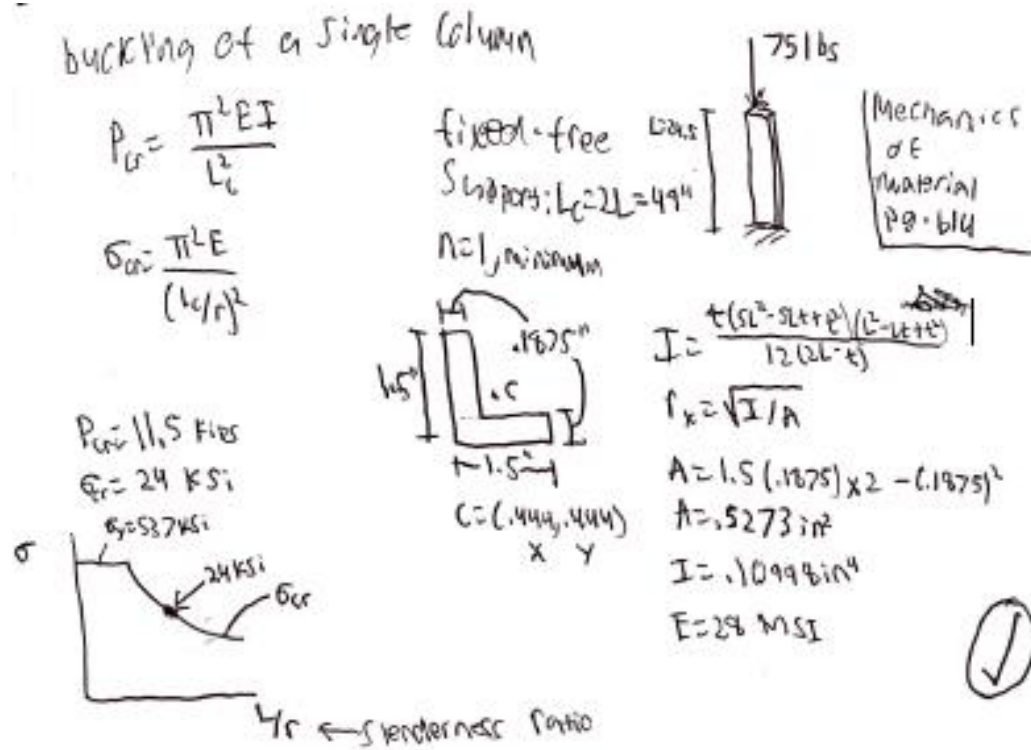
$$\frac{200 \text{ W}}{36.5 \text{ ft}^2} \approx 5.5 \frac{\text{W}}{\text{ft}^2}$$

$$T_{\text{rise}} \approx 22.5^\circ \text{F}$$



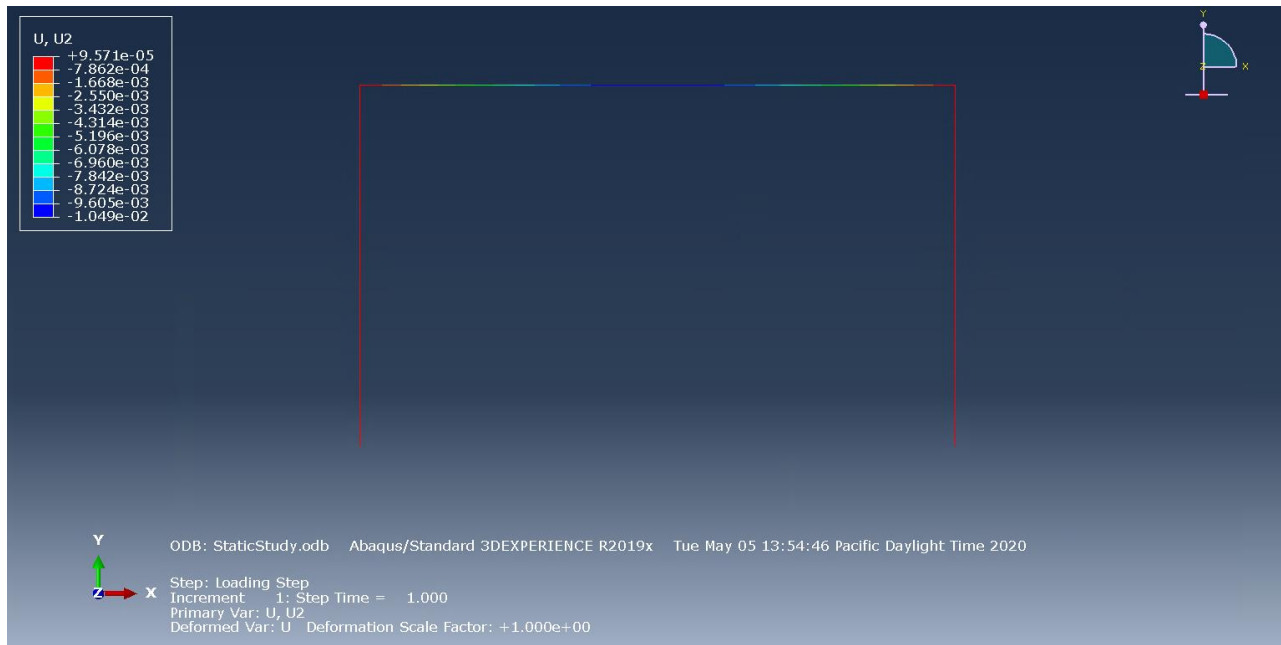
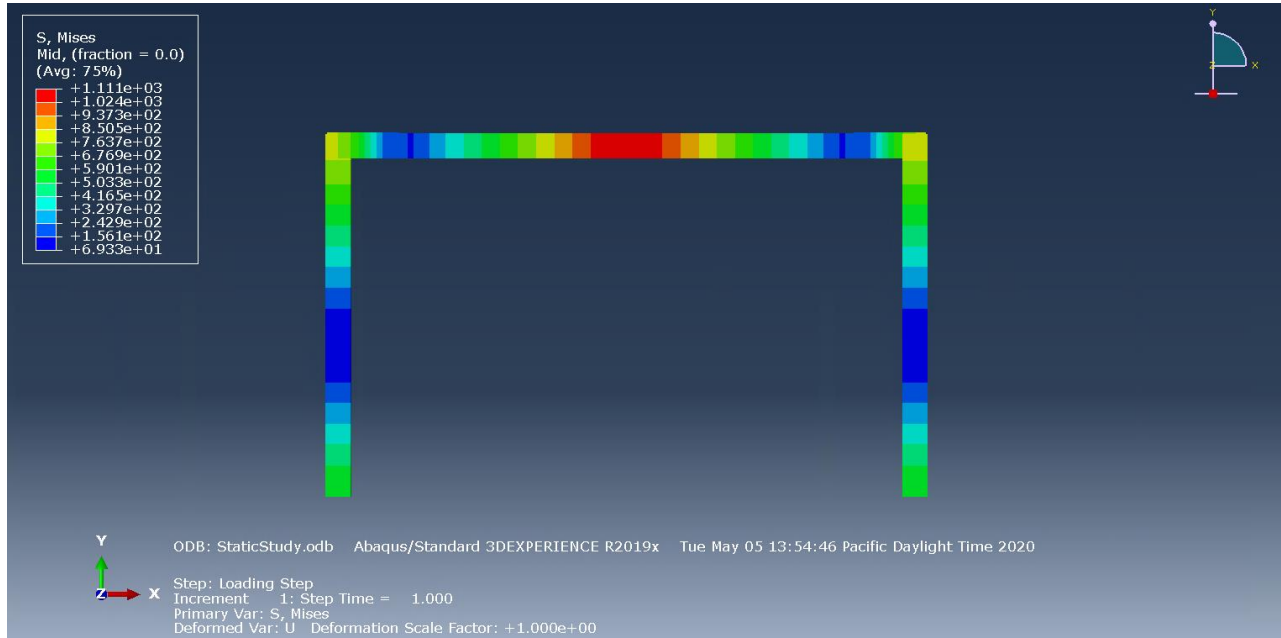
APPENDIX K

Stress Hand Calculation



APPENDIX L

Abaqus Results



Bill of Materials with Cost Analysis

53

Spray Pipe			1		0
Spray Pipe End Cap			1		0
Spray Pipe Mounting Plate			1		0
Barbed Hose Connector			1	1.71	1.71
m6 Hex Bolt 18mm			12	10.91	10.91
m6 Hex Nut			12	2.59	2.59
m6 Washer			12	4.29	4.29
5_16_C Hex Bolt			29	8.97	8.97
5_16_C Locknut			29	5.77	5.77
5_16 Washer			29	5.27	5.27
.4375 13 Hex Bolt Partially Threaded			12	9.68	9.68
Split Lock Washer			12	8.62	8.62
0.5 13 Hex Nut			12	9.33	9.33
1.75 OD Spring Washer			12	10.22	10.22
0.375 Mass Set Screws			4		0
1.035 OD Washer			2	7.81	7.81
0.675 OD Washer			1	9.15	9.15
0.81 OD Washer			1	0.00	0
0.3125 18 Hex Bolt Fully Threaded			1	8.97	8.97
			52		537.59
			240		

without sheet metal purchase

APPENDIX N

Drawing List and Part Numbers

DB300CP000 – Master Finishing Tank Assy

DB300CP00-EXP - Final Assy (Exp)

DB300CPB000 - Base Assy

DB300CPB001 – Caster Wheels

DB300CPB002 – Sound Paneling

DB300CB100 – Frame Assy

DB300CPB101 – Bottom Frame A

DB300CPB102 – Bottom Frame B&D

DB300CPB103 – Bottom Frame C

DB300CPB104 – Vertical Frame A

DB300CPB105 – Vertical Frame B

DB300CPB106 – Vertical Frame C

DB300CPB107 – Vertical Frame D

DB300CPB108 – Spring Rail A&B

DB300CPB200 – Sheet Metal

DB300CPB201 – Side Plate A&C

DB300CPB202 – Side Plate B

DB300CPB203 – Side Plate D

DB300CPB204 – Bottom Plate

DB300CPB300 – Lid Assembly

DB300CPB301 – Lid

DB300CPB302 – Handle

DB300CPB303 – Sound Paneling

DB300CPT000 – Tub Assembly

DB300CPT001 – Tub Shell

DB300CPT002 – Drain Pipe

DB300CPT003 – End Plate A
DB300CPT004 – End Plate B
DB300CPT005 – Spring Rail C&D
DB300CPV000 – Vibration Assy (EXP)
DB300CPV100 – Mr. Deburr Spring Assembly
DB300CPV101 – Spring
DB300CPV101 – Plastic Holder
DB300CPV200 – Motor Components
DB300CPV201 – .75 HP Motor
DB300CPV202 – Base Plate
DB300CPV203 – Pulley
DB300CPV204 – Belt
DB300CPV300 – Shaft-Bearing Components
DB300CPV301 – Split Tapered Bushing Bore Pulley
DB300CPV302 – Bushing
DB300CPV303 – Eccentric Mass
DB300CPV304 – Shaft
DB300CPV305 – Bearings
DB300CPV400 – Support Structure
DB300CPV401 – Angle Steel
DB300CPV402 – Bearing Box
DB300CPPF00 – Mr. Deburr Pipe Assembly
DB300CPF001 – Spray Pipe
DB300CPF002 – Spray Pipe End Cap
DB300CPF003 – Spray Pipe Mounting Plate
DB300CPF004 – Barbed Hose Connector
DB300CPX00 – Fasteners
DB300CPX001 – m6 Hex Bolt 18mm
DB300 CPX002 – m6 Hex Nut
DB300CPX003 – m6 Washer

DB300CPX004 – 5_16_C Hex Bolt
DB300CPX005 – 5_16_C Locknut
DB300CPX006 – 5_16 Washer
DB300CPX007 – .4375 13 Hex Bolt Partially Threaded
DB300CPX008 – Split Lock Washer
DB300CPX009 – 0.5 13 Hex Nut
DB300CPX010 – 1.75 OD Spring Washer
DB300CPX011 – 0.375 Mass Set Screws
DB300CPX012 – 1.035 OD Washer
DB300CPX013 – 0.675 OD Washer
DB300CPX014 – 0.81 OD Washer
DB300CPX015 – 0.3125 18 Hex Bolt Fully Threaded

APPENDIX O

Design Verification Plan & Report

Senior Project DVP&R

Date: 4/28/20	Team: The Three Stooges	Sponsor: Daniel Ochoa: C&M Topline	Description of System: Vibratory Tumbling Machine
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TEST PLAN

Item No	Specification #	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES		TIMING		Test Result
						Quantity	Type	Start date	Finish date	
1	1	Noise Test (dB)	65 dB	Jared	FP	1	Sys	5/10/2020	11/16/2020	Pyramid Foam
2	2	Motor Heat Test	104 F	Jared	FP	1	C	5/10/2020	11/16/2020	No Motor Casing
3	3	Hourly Power Consumed	.75 kWh	Aaron	FP	1	Sys	6/1/2020	TBD	
4	4	Operator Set Up Time (min)	15 mins	Laurence	FP	1	Sys	6/1/2020	TBD	
5	5	Moveable	Inspection	Laurence	FP	1	Sys	6/1/2020	TBD	
6	6	Deburrs Parts	Inspection/Previous	Aaron	FP	1	Sub	6/1/2020	TBD	
7	7	Manufacturing Cost	\$1,500	Jared	FP	1	Sys	6/1/2020	TBD	
8	8	Total Part Load	Max 250 lbs	Aaron	CP	1	Sys	6/1/2020	TBD	

APPENDIX P

Testing Plans

1. Noise Test (dB)

Description of Test: Test the prototype for the amount of noise reduced by the new design of the Mr. Deburr

Required Prototype:

- The full completed prototype is needed

Required Location:

- The Bonderson room where the machine will be stored

Required Equipment:

- A phone that can measure db
- PPE required is a mask
- Safety glasses
- Ear plugs

Testing Protocol:

1. Open the db measuring app on the phone
2. Place the phone as close as possible to the machine
3. Press record for 30 seconds to get the average ambient db in that timeframe
4. Load the ceramic media into the tub
5. Plug in Mr. Deburr machine to turn on machine
6. Press record for 30 seconds to get the average db in that timeframe
7. Close the lid on the machine
8. Press record for 30 seconds to get the average db in that timeframe
9. Compare the db with and without the lid to show a difference
10. Unplug machine

Data:

- db without lid
- db with lid
- Ambient db level
- Percent Difference compared to the ambient db level

2. Motor Heat Test

Description of Test: Test the prototype for the temperature rise inside of the machine casing to make sure the motor doesn't overheat

Required Prototype:

- The full completed prototype is needed

Required Location:

- The Bonderson room where the machine will be stored

Required Equipment:

- A temperature probe
- PPE required is a mask
- Safety glasses
- Ear plugs

Testing Protocol:

1. Measure the temperature in the room
2. Plug in Mr. Deburr machine
3. Measure the ambient temperature inside the Mr. Deburr casing
4. Turn on and run the machine
5. Continuously measure the temperature in the casing until it reaches steady state which should be achieved after five minutes

Data:

- Ambient temperature in the room
- Ambient temperature in the casing
- Temperature in the casing after it reaches steady state
- Dimensions of the machine casing
- Uncertainty analysis of the dimensions

3. Hourly Power Consumed

Description of Test: Test the hourly power consumed of the motor and machine

Required Prototype:

- The full completed prototype is needed

Required Location:

- The Bonderson room where the machine will be stored

Required Equipment:

- A power meter
- PPE required is a mask
- Safety glasses
- Ear plugs

Testing Protocol:

1. Plug the power meter into the wall
2. Plug the motor into the power meter
3. Run the machine for 1 minute
4. Record the power displayed on the meter
5. Multiply the power by 60 to get the hourly power
6. Repeat the test 5 times to get an average

Data:

- 5 trials of the power consumed in 1 minute
- Hourly power consumed
- Average power consumed in a hour

4. Operator Set Up Time

Description of Test: Test the amount of time required to set the machine up to be able to run. Ideally this should be less than 15 minutes.

Required Prototype:

- The full completed prototype is needed

Required Location:

- The Bonderson room where the machine will be stored

Required Equipment:

- A timer
- PPE required is a mask
- Safety glasses

Testing Protocol:

1. Start the timer
2. Correctly tension the belt
3. Load the media into the tub
4. Load parts into the machine to be deburred
5. Place the lid on top of the machine
6. Turn the motor on
7. Stop the timer

Data:

- Time taken to run from steps 1-7

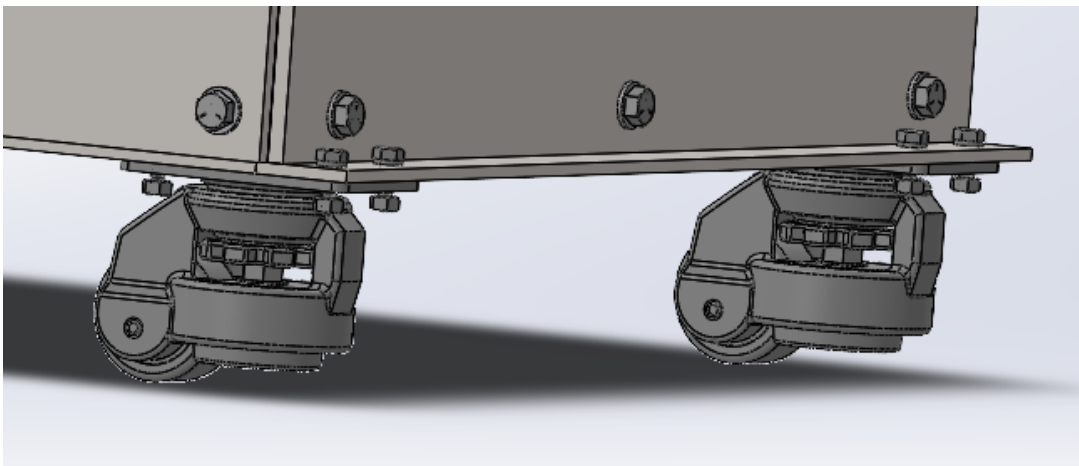
APPENDIX Q

Operators Manual

Anchoring Your Mr. Deburr Machine

CAUTION: This equipment is heavy. Observe good and safe practice when attempting to install, move, maintain, or otherwise work on it. Failure to observe this caution may create a safety hazard. Your machine will either come equipped with leveling caster wheels or without.

- If the machine does not have leveling caster wheels; **the machine must be level, and anchored to a solid surface. A concrete floor or concrete pad is recommended.** *Machines that have ran un-anchored or anchored to any vibration dampening devices will void all warranties.*
- If the machine does have leveling caster wheels; the machine must be level and stationed on a solid surface. The leveling pad must be extended prior to the machine being used. Turn the thumbwheel to lower or raise the leveling pad



(An example of a machine with leveling caster wheels)

Anchor bolts are provided with your machine purchase

Model DB300: 3/8" – 1 7/8" Sleeved Anchor Bolts, use 3/8" concrete drill

Model DB600: 1/2" – 3" Sleeved Anchor Bolts, use 1/2" concrete drill

To Anchor:

1. Locate your machine in the desired location
2. Mark the location with a pen or marker through the mounting holes
3. Create the anchor points using the appropriate drill per your model listed above

Periodically check these anchor bolts to make certain that the vibrations have not caused loosening. It is important that your machine remain level and securely mounted to the floor in order to prevent damage to your machine. The machine may be shimmed with a flat washer to make up for irregularities in the floor. The machine should not be run on a pallet, even temporarily.

External Vibrations

The Mr. Deburr will transfer vibration to it's surrounding. If vibration sensitive equipment is located nearby, utilize the findings below as a guidance.

Model DB300:

- When anchored to the floor, external vibration was measured to be ____ at ____ feet around the machine on ____ surface.
- When the leveling pad is extended, external vibration was measured to be ____ at ____ feet around the machine on ____ surface.

Occupational Noise

Mr. Deburr systems produce levels of noise consistent with their intended purposes. The level and spectral content of noise produced is dependent on the tub size, the degree that the bowl is maintained in proper operating condition, the abrasive/media and accessories used, the specific application, use or not of the optional lid, and the surrounding environment. Noise levels produced by various Mr. Deburr vibratory systems, as measured at the C&M Topline factory, range from 81 to 93 decibels (See table below for more information). Product operators and persons in the immediate product vicinity should be protected from excessive noise levels as prescribed in OSHA regulation 29, part 1910.95 titled "Occupational Noise Exposure".

The following data was collected on the model DB300 utilizing ____ media with ____ (parts) for the purposing of ____ (Deburring/Polishing).

Machine Configuration	dB Reading
No Lid	
Abatement Lid	
Housing Cover	

Media and Part Loading

If you purchased a media starter kit from C&M Topline, install the media and compounds into the chamber using the prescribed quantities and mixtures. Otherwise follow the instructions provided. Do not exceed the media load prescribed for your machine.

Machine	Ceramic media load	Plastic Media Load	Part load	Max. total load
DB300	TBD	TBD	TBD	TBD
DB600	400 lbs.	300 lbs.	450 lbs.	900 lbs.

Overloading the machine may significantly reduce its service life. If you use steel media, note that steel media weights generally 200 to 350 pounds per cubic foot (Non steel media generally weighs 20 to 125 pounds per cubic foot). To avoid possible machine damages do not add media and parts to the machine such that the total specified machine load is exceeded.

Using too little media in your Mr. Deburr machine will significantly reduce vibratory motion and adversely affect processing time and quality. You should have sufficient media in your Mr. Deburr such that the media rises to less than 5 inches (3-4 inches is ideal) of the tank's upper edge when the machine is operating. Add media as required to maintain this minimum quantity.

Place your parts into the tub. Note the above part loads. The part load prescribed is not a maximum but rather a nominal weight. The geometry, material, and weight of your parts will determine the part load you can achieve. The greater the total load, the harder the machine must work to sustain suitable energy delivery. Do not exceed the maximum total loads specified. To do so may shorten the life of your machine, and/or diminish its process capability.

Vigorous media and part movement is evidence of good finishing action. A rotating wave with the highest portion of the wave rising up the back wall of the machine and the front portion of the wave substantially below the rear portion should exist. With good action the parts circulate and rise to the front of the tank, then cascade down the wave to the back of the tank. Should you not observe this quality of motion, check that the machine is loaded properly (see the previous table).

Fluid System and Nominal Operation

Your Mr. Deburr system was shipped from the factory with a re-circulating fluid system that includes a pump, pump bracket, connecting hose, and recovery sump bucket that serves to collect the fluid output from the tank drain. Screw the hose barb on the hose that is connected to the pump into the petcock at the top of the tank. The bucket goes under the tank drain and the pump hangs in the bucket with the bracket provided. Fill the 7 gallon bucket included with DB300 systems with 6 gallons of water. Fill the 10 gallon bucket included with DB600 systems with 9 gallons of water and add finishing compound fluid. The compound should be mixed at a ratio of 1-4 ounces per gallon of water. Figure 2 shows the standard DB300 system. Note cutout in bucket is for display purposes. During processing ensure that the switches to the Mr. Deburr motor and the fluid pump are both in the "on" position. Adjust the flow rate of the fluid with the petcock that is connected to the fluid pipe. The flow rate should be adjusted down so that the media is wet but with little to no accumulation of standing water in the bottom of the tank while the machine is running. The fluid should just drip into the machine while it is running. If you notice a large amount of foam in the bucket, reduce the water flow as well. The fluid should be changed often, at least once every 8 hours of operation. If the fluid is very dirty the media will become sticky and stop turning in the tank. Dirty fluid also causes more foaming during operation and can become rancid. It is also important that the pump remain submersed while running. If the pump is allowed to run dry, it will become very hot. This will shorten the life of the pump if not burn it out completely. Also ensure that the pump is suspended off the bottom of the bucket using the included bracket. This prevents the excess sediment that collects in the bucket from prematurely reducing pump life. To make changing of the circulation solution easier, put a disposable plastic bag in the bucket before filling it with water and compound. The bag should be 3 mil or 4 mil thick. Simply pour off the liquid and dispose of the solid waste using the bag. You may also set our

machine up to run with a flow-through fluid system or a batch type (closed) system. Drain plugs are available that will allow the machine to operate as a closed system.

Avoid Fire and Explosion Hazards

The use of fluids other than water and specified soaps in your Mr. Deburr system (or an associated fluid re-circulating system) may create a fire/explosion hazard that could result in personal injury, or death. Use only clean water with recommended compounds. Avoid eye damage, flesh burns, and/or poisoning. Many vibratory processing soaps, compounds, and media are acidic or caustic. Wear appropriate flesh and eye protection gear when using vibratory soaps and compounds, and when working around and with your Mr. Deburr system. Do not ingest these materials. MSDS sheets are available for all soaps, compounds, and media sold by C&M topline at www.cmtopline.com. Obtain, read, and apply the precautions specified in the MSDS sheets.

Precautions with Fluids and Other Materials

Only use fluid as recommended by C&M Topline. The Mr. Deburr urethane liner is very tough and resistant to abrasion. Certain chemicals may however, attack it. In example, mineral spirits may leach agents from the urethane and reduce its service life. If in doubt consult with C&M Topline or a chemist who is knowledgeable about urethane. Remember, never use flammable chemicals in your Mr. Deburr system. Likewise, many chemicals can damage the pump and associated apparatus. Additionally, there are many different chemicals in use as coolants, cutting fluids, and for other purposes commonly found in facilities such as machine shops. C&M Topline cannot guarantee the compatibility of the various soaps and fluids that we sell with the chemicals and fluids you may use. You as the consumer must assure that the fluids and chemicals that you elect to use are compatible with each other and with other materials. It is possible that chemical reactions between fluids and/or materials that you use could be a threat to human health and safety; and/or create conditions that are deleterious to the Mr. Deburr system, peripheral equipment, and/or your parts. There are many compounds that are available to use in vibratory machines depending on the materials, media, and results that you are using and desire. Fluids and compounds serve to improve finish, speed results, extend media life, and in some cases to retard oxide formation. The following is a partial list of guidelines:

Aluminum

When processing aluminum or other non-ferrous materials to a burr free state with matte finish select liquid soap such as VF77 and mix it with water at a concentration of 1 to 4 ounces per gallon of water. Adjust the fluid valve to deliver a steady trickle of fluid to the tank. To improve your parts surface condition post processing always rinse your parts in clean water shortly after removing them from the chamber, then dry them to minimize spotting. Remember that many metals will oxide rapidly when machining, etc. expose fresh metal (as is the case with vibratory processing). If this is a problem there are various chemicals that are available that you may use to dip your parts in

post vibratory process to minimize oxide formation. Consult with your metals supplier, or C&M Topline.

Steel

When processing steel and other ferrous materials to a burr free state with a matte finish select a liquid soap that also contains a rust inhibitor such as VF100 and mix it with water at a concentration of 1 to 4 ounces per gallon of water. Adjust the fluid valve to deliver a steady trickle of fluid to the tank. To improve your parts surface condition post processing always rinse your parts in clean water shortly after removing them from the chamber, then dry them to minimize rusting. Remember that ferrous metals will oxide rapidly when machining, etc. expose fresh metal (as is the case with vibratory processing). VF100 will provide temporary retardation of rust formation. Depending on humidity, temperature, and other conditions the temporary rust inhibition will be from a few hours to several days. If your materials require longer protection, concentrated rust inhibitors are available that you may use to dip your parts in post vibratory process to inhibit rust formation for several days to several months. NOTE: VF100 may be used as a vibratory soap in concentrations up to 8 ounces per gallon of water; used as such it provides superior rust retardation. For special problems with rust or other staining consult with your metals supplier, or C&M Topline.

Polishing

Many materials may be brought to a fine, lustrous, low RMS finish by using non-abrasive ceramic polishing media together with a burnishing compound such as VF103 or VF150 mixed with the water. Mix these compounds with water at a concentration of 1 to 4 ounces per gallon of water. Clean and dry your parts as described above immediately after processing. Many materials may be polished to a high luster using special media such as walnut shell, corncob, etc. Typically, these types of media are used dry, without the use fluids. If you wish to use dry process media do not use the fluid system. It will also be necessary to plug the outlet drain of your Mr. Deburr chamber to prevent the media from escaping out the outlet. This can be done using common plumbing devices available at ordinary hardware stores, or from C&M Topline. Never operate the fluid pump dry. Doing so may damage the pump.

Tips for Optimal Operation

It is impossible to anticipate all possible combinations of materials, shapes, media, and compounds that customers may use in this equipment. It is therefore, not possible to provide specific directions for media selection, compounds, process times, etc. There are, however, general guidelines that will help to target the optimum process. These include:

- Select your media and compounds after consulting with C&M Topline, a qualified media supply house, or your distributor. See the previous section on using fluids and compounds.

- Clean your equipment regularly. This will help in keeping your processed parts free of stains, dust, etc.
- Use fresh fluids and change them often. It is recommended that you change fluids once a day or every 8 hours of operation. Organic fluids left sitting for many days can turn rancid.
- Clean and rinse parts quickly after processing. Nonferrous parts may stain if not cleaned and dried properly. Ferrous parts may rust. There are compound additives that will help in removing and/or preventing part staining.
- Media wears out in time. The longer media is used the less its abrasive power. Softer materials such as aluminum tend to clog the media, harder materials tend to wear the surface of the media. The use of fluids will help to optimize your results. C&M Topline recommends that you establish a regular schedule for changing and discarding your media. You will gain knowledge regarding process times, and media life. Keeping records of your process variables will help you optimize your process.
- Ensure your machine is anchored directly to a solid concrete surface. Mounting to something such as a pallet or placing vibration dampening between the machine and floor may cause damage to the motor and will void the warranty.

Further Troubleshooting

- Check the V belt to see that it is not too tight. It should have about 3/4" of deflection half way between the pulleys at 2-3 lbs for the DB300 and 2" of deflection for the DB600.
- The media level should be 5" from the top of the tank. If the level of media drops too low, the media will not tumble as vigorously.
- Most of the time the problem is that the media has become dirty or contaminated, which makes the media sticky and prevents proper tumbling. Should the media become dirty or contaminated, thoroughly clean the fluid container, refill it with clean water and add two or three cups of some low foaming detergent such as "Simple Green" or "409". Run the machine 5 to 10 minutes and repeat the process once more. Then refill the container with water and your regular deburring compound. If you have this problem repeatedly, increase the amount of compound and clean the fluid container more often.

Recommended Maintenance

Maintenance consists of cleaning the unit, assuring mechanical fasteners are secure, assuring the drive belt is properly tensioned, and occasionally lubricating the drive shaft bearings.

Simply unscrew the 7 (8/9?) butterfly bolts on the front facing side of the machine and set aside the paneling to access the inner components of the machine.

After Initial 24 Hrs of Operation

- Adjust Drive Belt Tension – 3/4" Deflection at 2-3 lbs for the DB300 – 2" Deflection at 2-3 lbs for the DB600
- Inspect For Loose Hardware including floor anchor bolts

Every 30 Days of Operation (Verify components of this section)

- Adjust Drive Belt Tension – 3/4" Deflection at 2-3 lbs for the DB300 – 2" Deflection at 2-3 lbs for the DB600
- Lubricate Bearings – NLGI#2 Lithium or Lithium Complex, Caution – Do not use excessive grease.
- Torque Bearing Mounts – 40-50 ft-lbs
- Torque Motor Mounts – 130-140 in-ozs
- Torque Bearing Shafts Sets – 65-70 in-ozs
- Torque Tub Mounts – 240-280 in-ozs
- Inspect For Loose Hardware including anchor bolts
- Clean as Required

Special note on bearing lubrication

Easy access to the bearing grease zerk fittings is provided. See figure3. Use a lithium-based grease available from any auto parts store. It is very important that you DO NOT OVER GREASE the bearings. Too much grease will cause overheating. One squirt with a hand grease gun every 100 hours of operation is sufficient. A small amount of grease at frequent intervals is preferable to a large amount at infrequent intervals. If the bearings seem to be changing pitch or noise volume it may be time to service or replace the bearing.

Visit www.cmtopline.com for replacement parts. We also offer full bearing assembly rebuilds. Contact us at info@cmtopline.com for details.

Special note about the motor mount and drive belt(s)

Do not over tighten the drive belt. The machine will run better with a drive belt that in another application would appear to be running too loose. Over tightening the drive belt will result in premature motor failure.

Warranty service

Should you require warranty service please contact C&M Topline or your distributor. C&M Topline may be reached at info@cmtopline.com. The motor manufacturer warrants the main drive electric motor; to obtain motor warranty service contact the motor manufacturer's service

center in your area. NOTE: when inquiring about warranty service or replacement parts please be prepared to provide the actual machine model number.

Modifications to your vibratory chamber

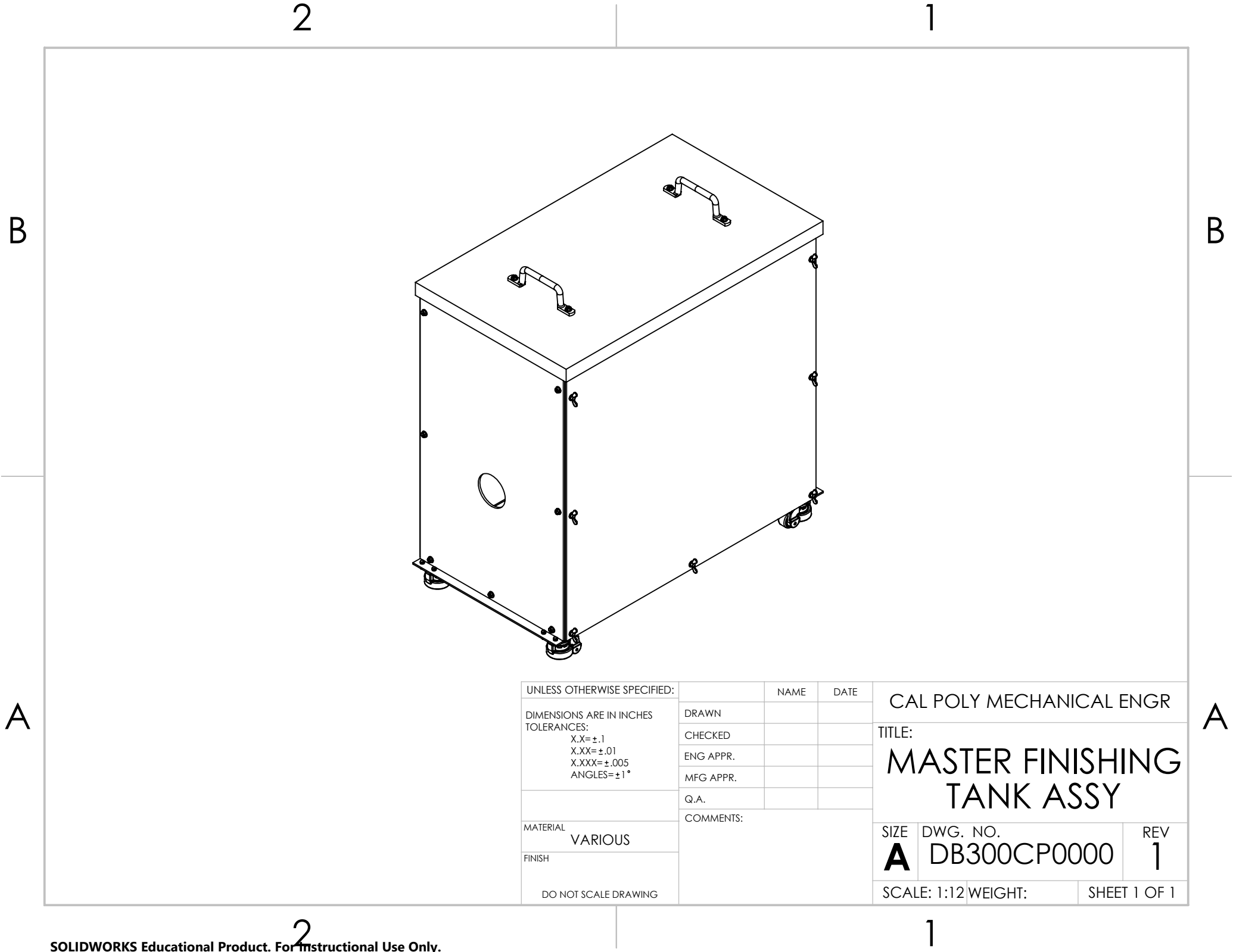
CAUTION: Modification of the machine from its as shipped condition from the factory may create a safety hazard, and may void the factory warranty. If you have any questions in this regard please consult C&M Topline before making any modifications.

Supplies and Parts

C&M Topline offers most media and compounds for sale on our website at cmtopline.com. A media and compound availability guide is included with this manual. We also have helpful tips and pictures on our Finishing 101 website section which includes real before and after finishing test results. All C&M Topline machines are produced with line replaceable parts. Many parts can be ordered directly online. See the following parts schematics to help identify your replacement parts needs.

APPENDIX R

Drawing Package



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X.XXX=±.005
ANGLES=±1°

MATERIAL VARIOUS

FINISH

DO NOT SCALE DRAWING

DRAWN

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:

NAME DATE

CAL POLY MECHANICAL ENGR

TITLE:

MASTER FINISHING
TANK ASSY

SIZE

A

DWG. NO.

DB300CP0000

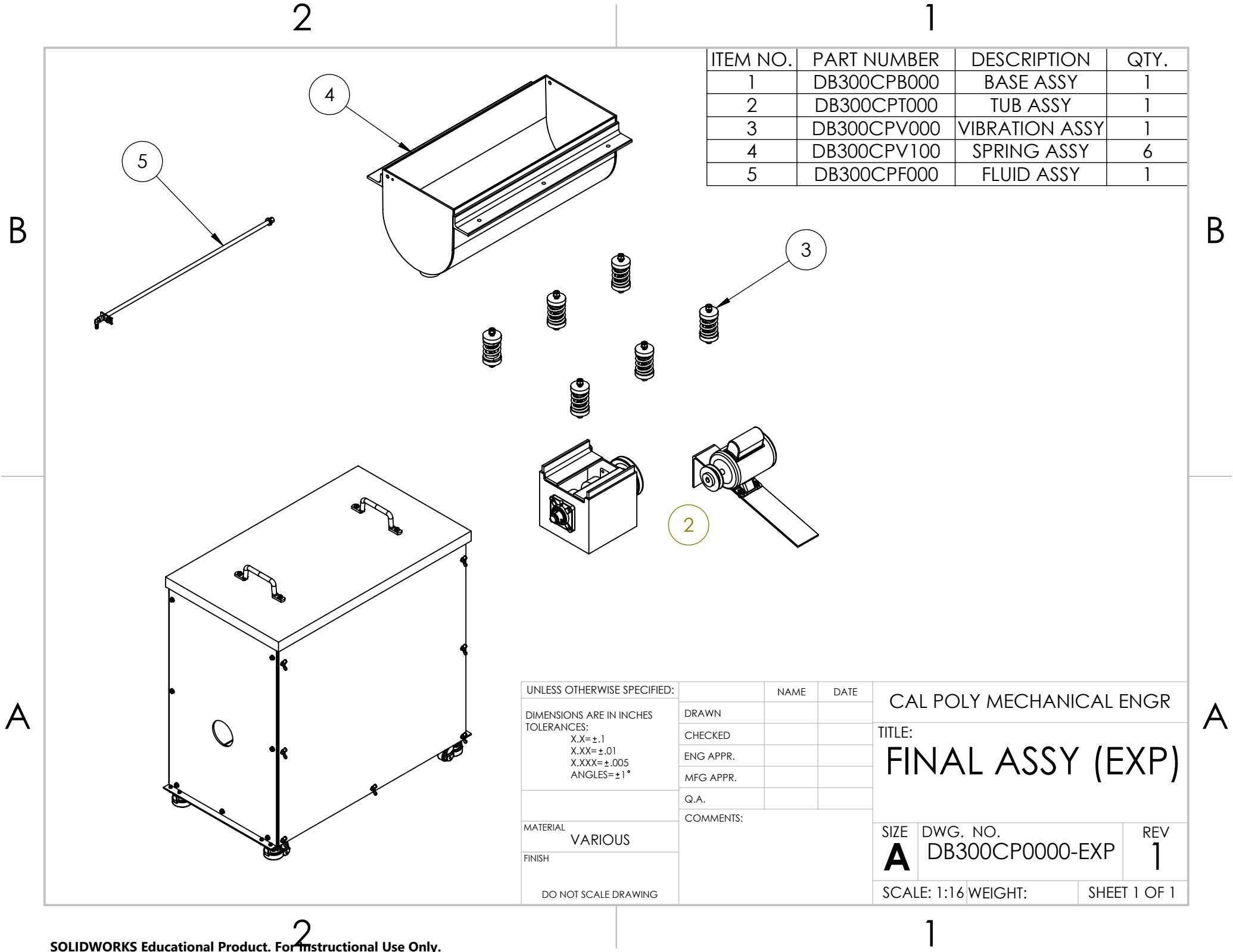
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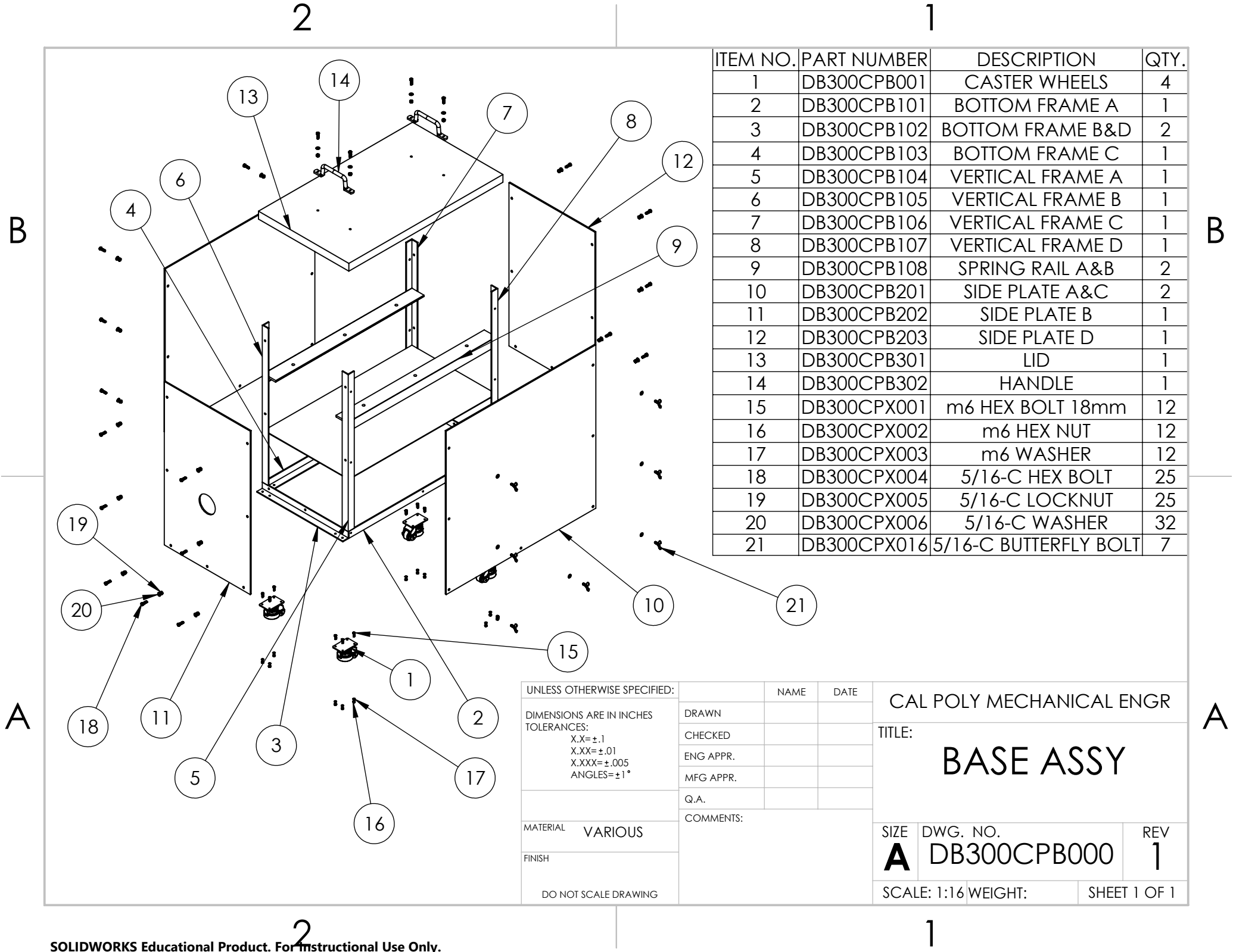
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SHEET 1 OF 1



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1	DB300CPB000	BASE ASSY	1
2	DB300CPT000	TUB ASSY	1
3	DB300CPV000	VIBRATION ASSY	1
4	DB300CPV100	SPRING ASSY	6
5	DB300CPF000	FLUID ASSY	1

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		MFG APPR.				
		Q.A.				
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VARIOUS				A	DB300CP0000-EXP	1
FINISH						
DO NOT SCALE DRAWING						



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	DB300CPB001	CASTER WHEELS	4
2	DB300CPB101	BOTTOM FRAME A	1
3	DB300CPB102	BOTTOM FRAME B&D	2
4	DB300CPB103	BOTTOM FRAME C	1
5	DB300CPB104	VERTICAL FRAME A	1
6	DB300CPB105	VERTICAL FRAME B	1
7	DB300CPB106	VERTICAL FRAME C	1
8	DB300CPB107	VERTICAL FRAME D	1
9	DB300CPB108	SPRING RAIL A&B	2
10	DB300CPB201	SIDE PLATE A&C	2
11	DB300CPB202	SIDE PLATE B	1
12	DB300CPB203	SIDE PLATE D	1
13	DB300CPB301	LID	1
14	DB300CPB302	HANDLE	1
15	DB300CPX001	m6 HEX BOLT 18mm	12
16	DB300CPX002	m6 HEX NUT	12
17	DB300CPX003	m6 WASHER	12
18	DB300CPX004	5/16-C HEX BOLT	25
19	DB300CPX005	5/16-C LOCKNUT	25
20	DB300CPX006	5/16-C WASHER	32
21	DB300CPX016	5/16-C BUTTERFLY BOLT	7

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
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ANGLES=±1°

MATERIAL VARIOUS

FINISH

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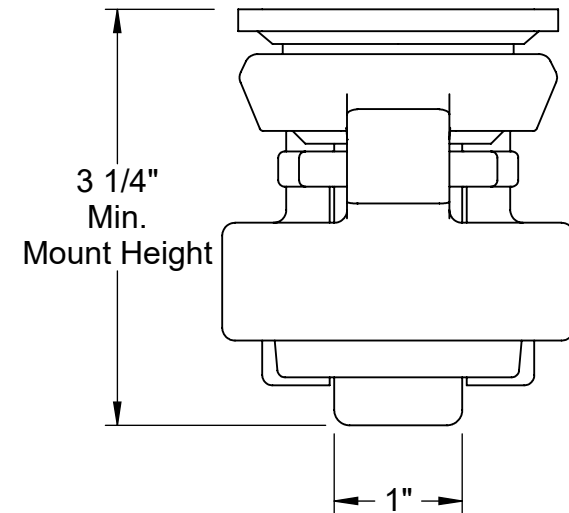
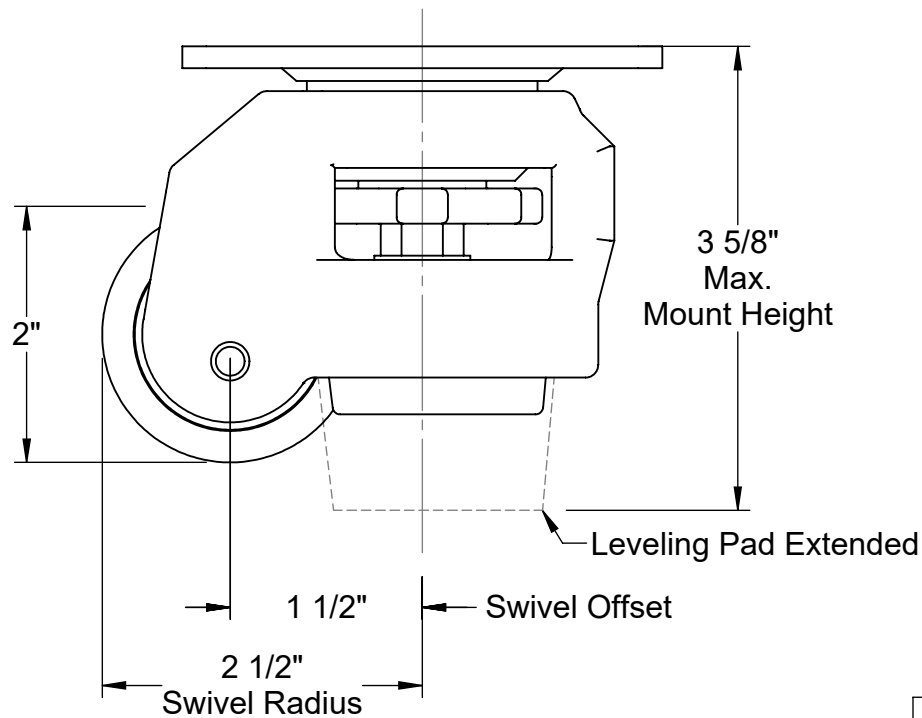
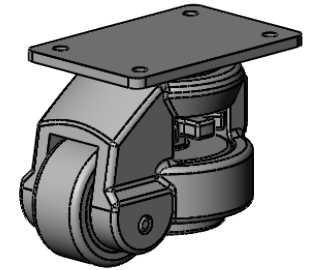
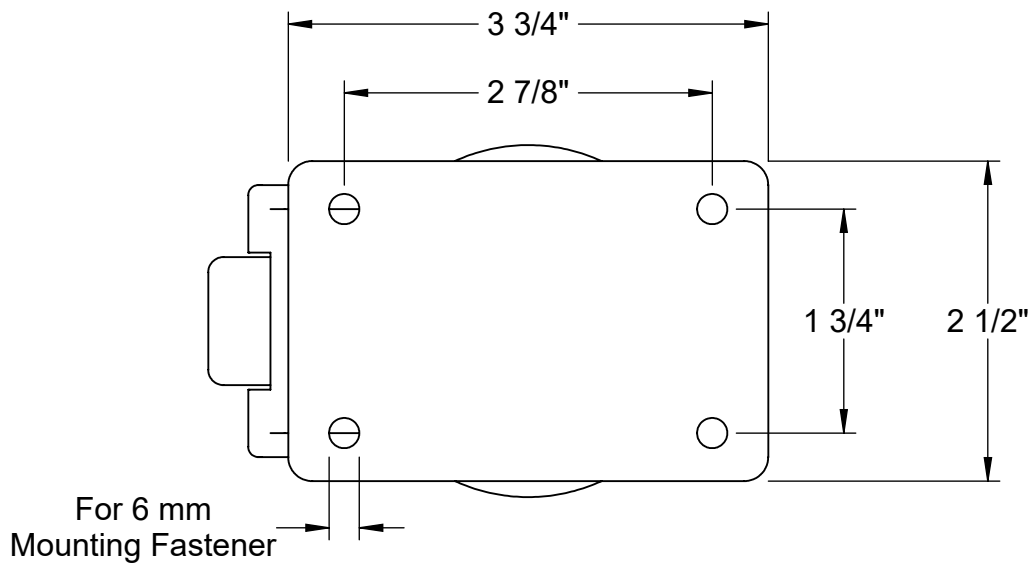
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CAL POLY MECHANICAL ENGR

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BASE ASSY

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		SHEET 1 OF 1



McMASTER-CARR CAD

<http://www.mcmaster.com>
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Information in this drawing is provided for reference only.

PART
NUMBER

24125T25

Leveling Plate
Caster

B

B

A

A

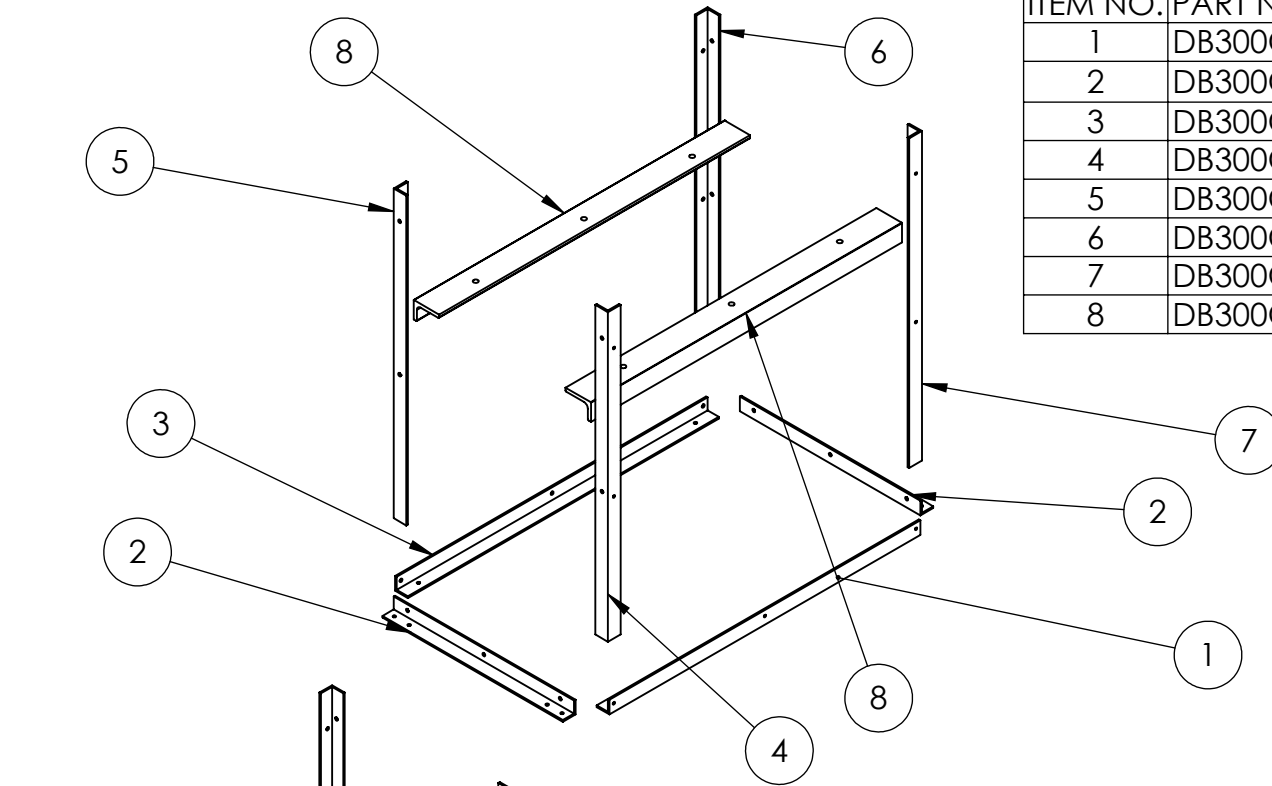
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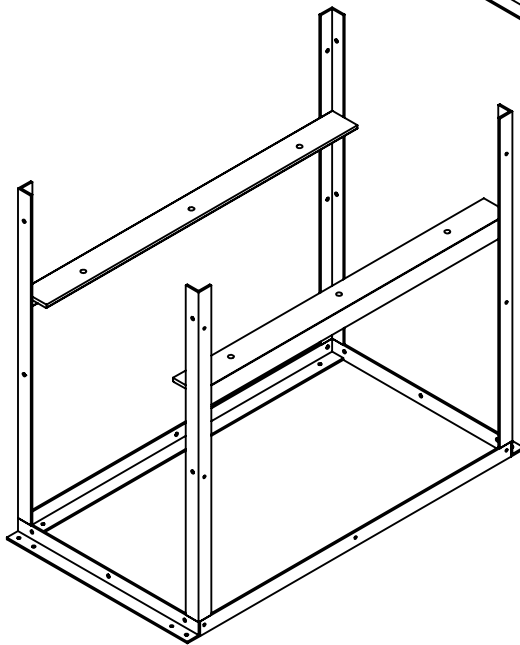
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2	DB300CPB102	BOTTOM FRAME B&D	2
3	DB300CPB103	BOTTOM FRAME C	1
4	DB300CPB104	VERTICAL FRAME A	1
5	DB300CPB105	VERTICAL FRAME B	1
6	DB300CPB106	VERTICAL FRAME C	1
7	DB300CPB107	VERTICAL FRAME D	1
8	DB300CPB108	SPRING RAIL A&B	2



WELD ALL AROUND



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
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X.XX=±.01
X.XXX=±.005
ANGLES=±1°MATERIAL
LOW-C STEEL

FINISH

DO NOT SCALE DRAWING

DRAWN

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:

NAME

DATE

CAL POLY MECHANICAL ENGR

TITLE:

FRAME ASSY

SIZE

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DWG. NO.

DB300CPB100

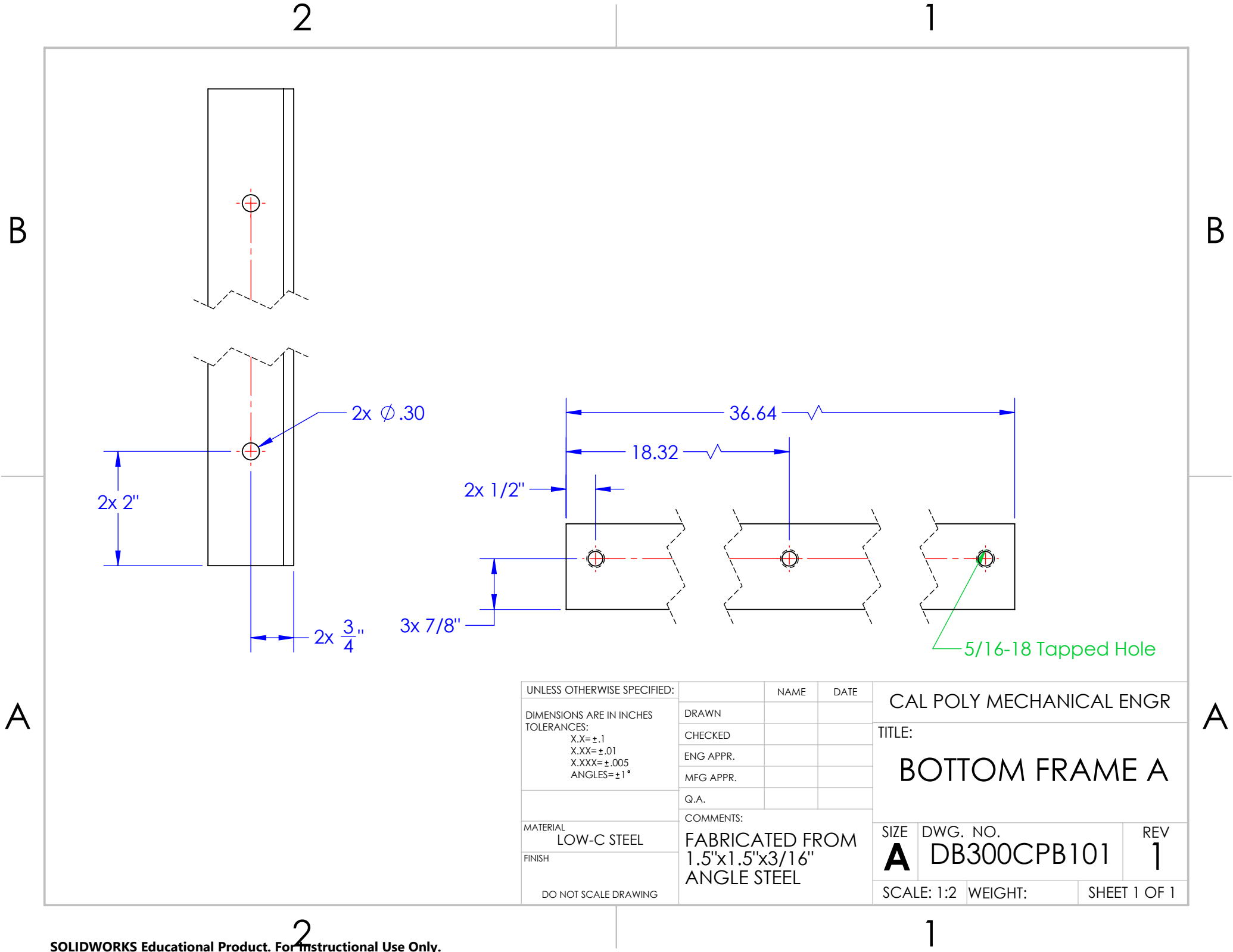
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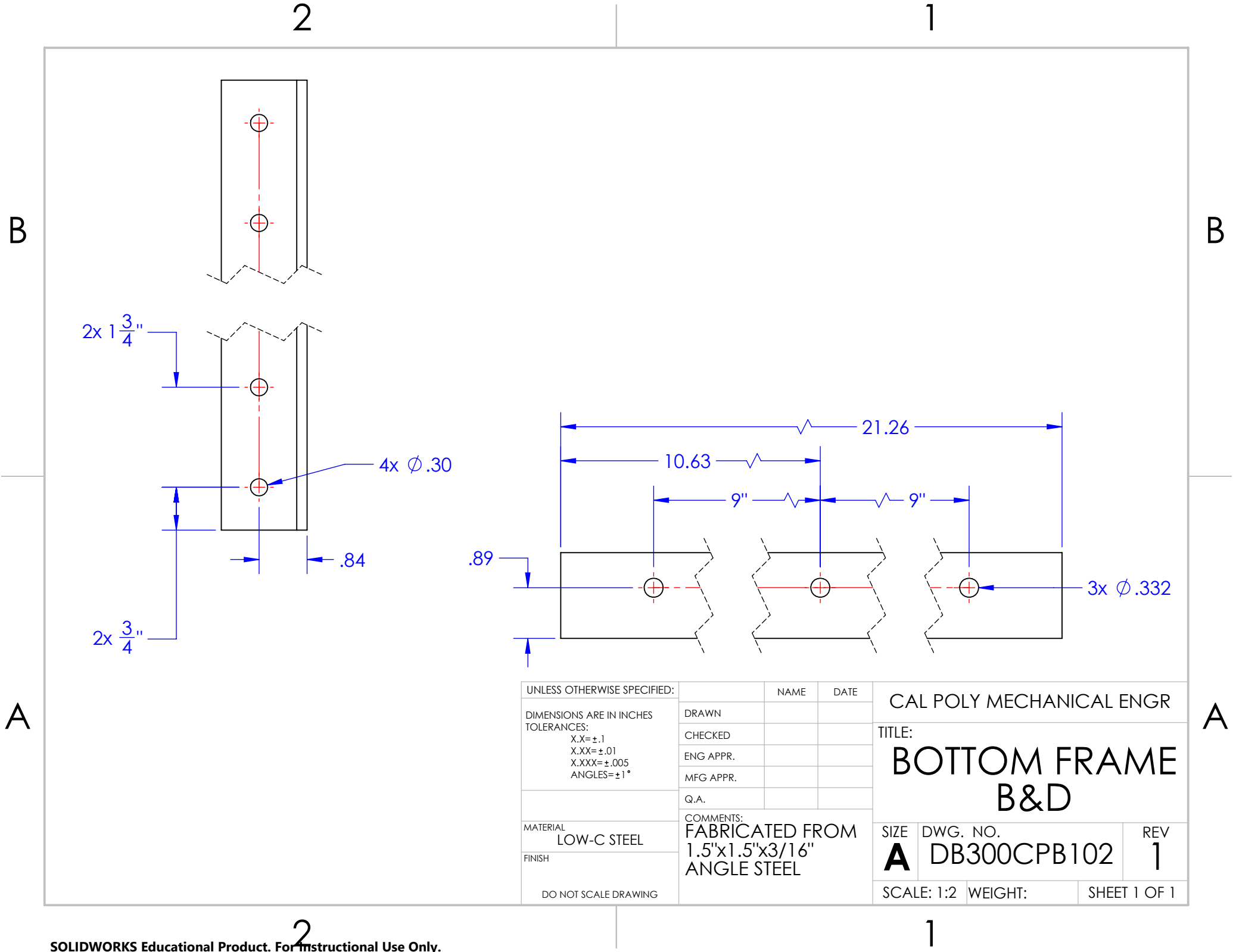
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SHEET 1 OF 1



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DO NOT SCALE DRAWING				WEIGHT:	SHEET 1 OF 1



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ANGLES=±1°

MATERIAL
LOW-C STEEL

FINISH

DO NOT SCALE DRAWING

DRAWN

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:
FABRICATED FROM
1.5"x1.5"x3/16"
ANGLE STEEL

NAME

DATE

CAL POLY MECHANICAL ENGR

TITLE:

BOTTOM FRAME
B&D

SIZE

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DWG. NO.

DB300CPB102

REV

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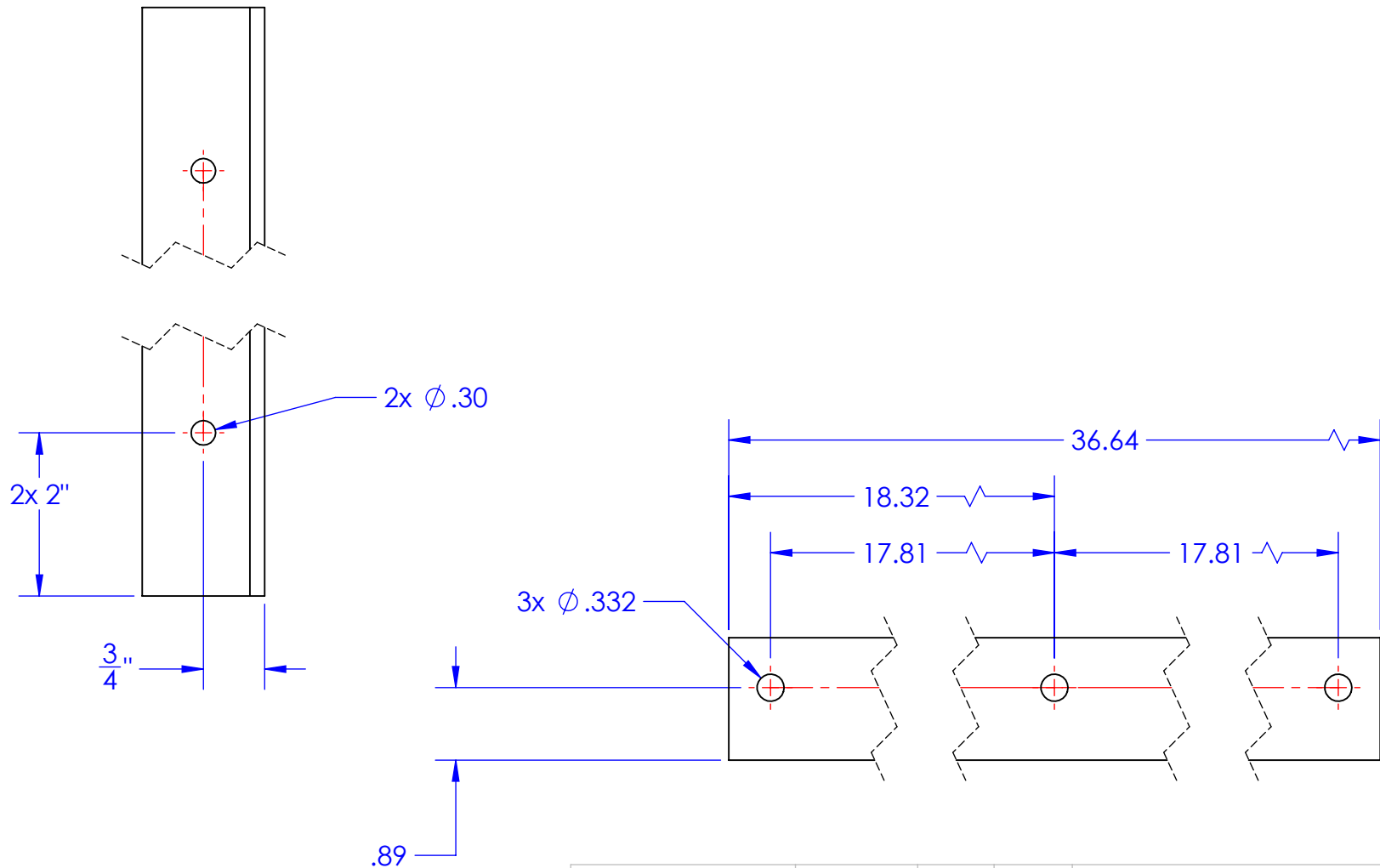
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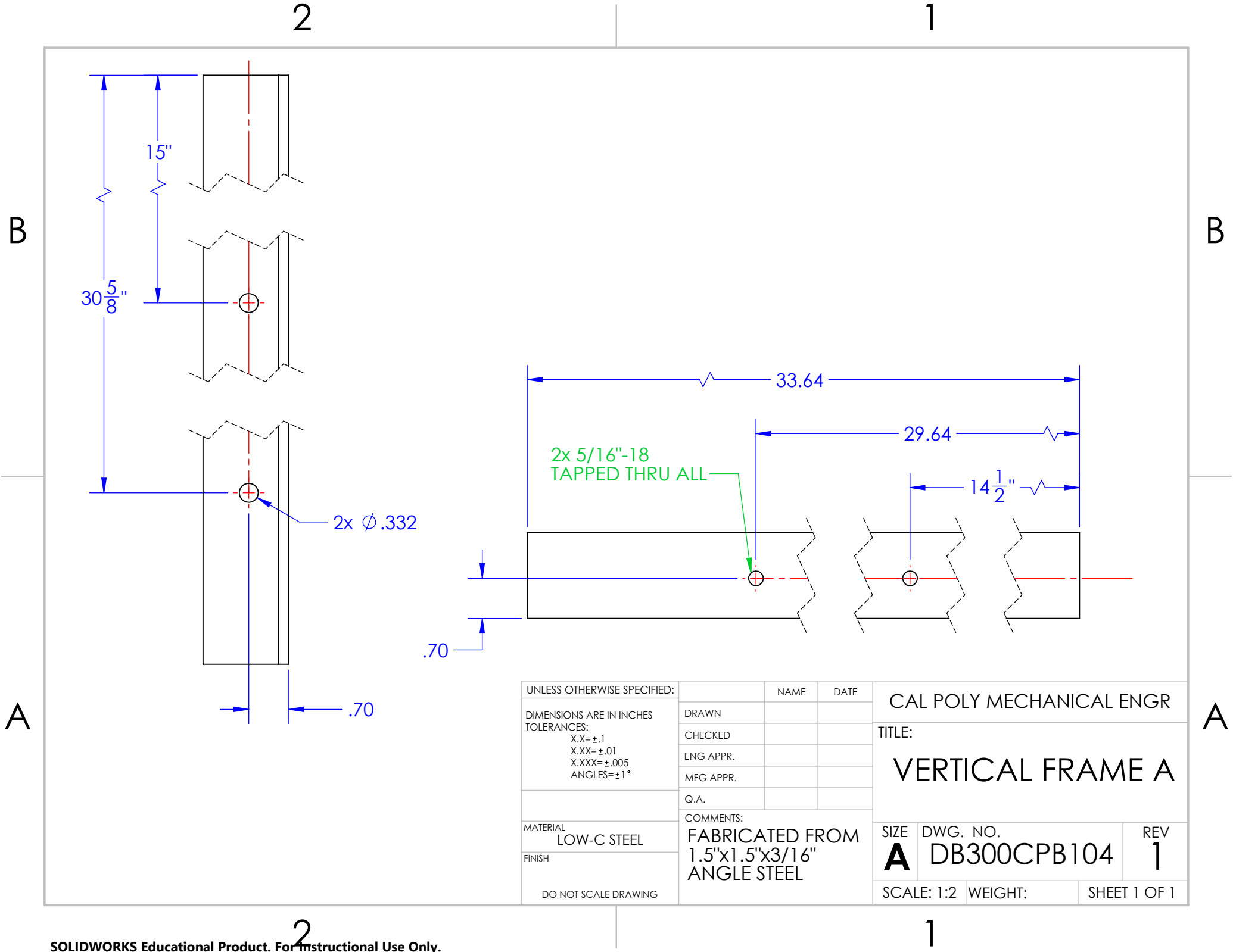
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B

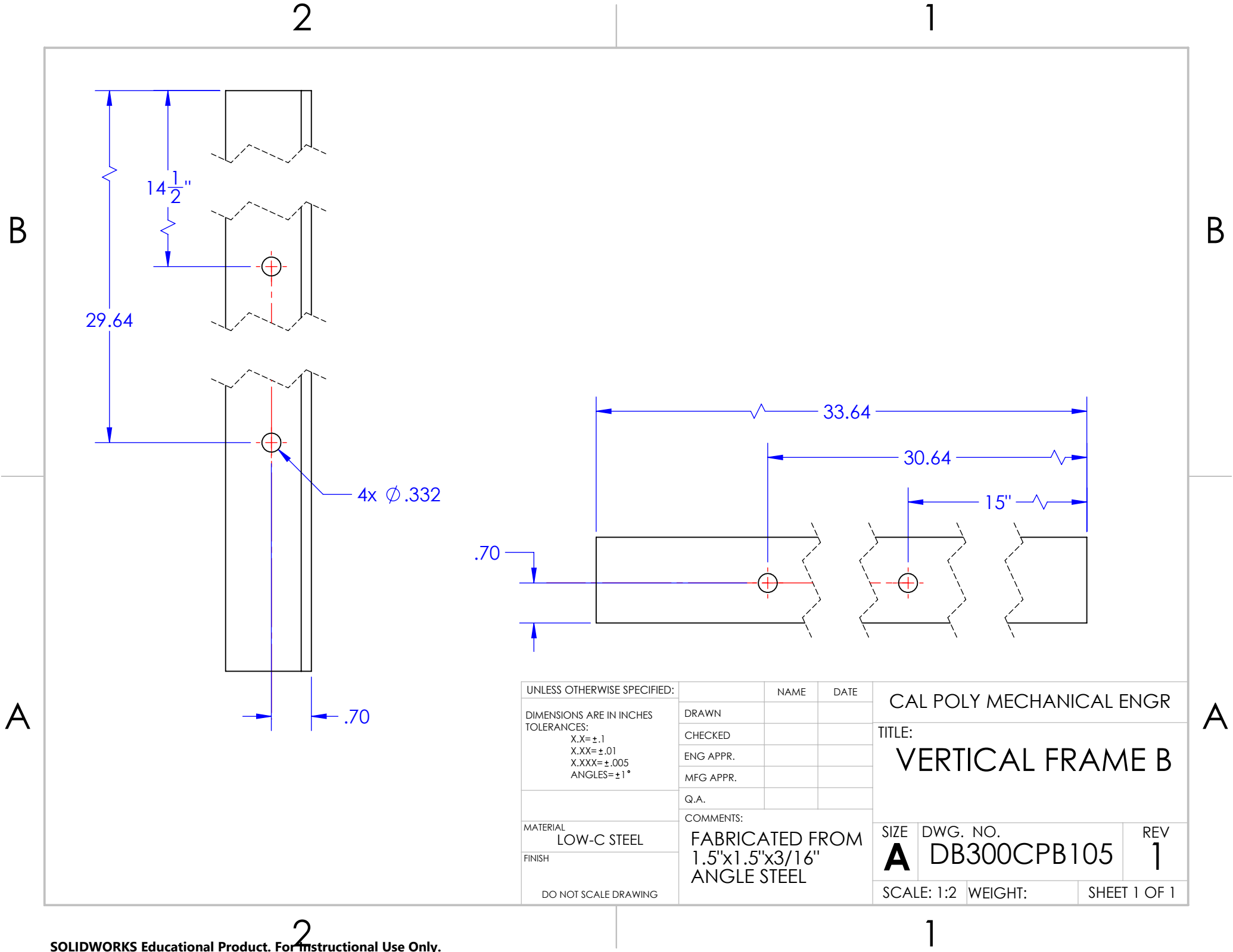
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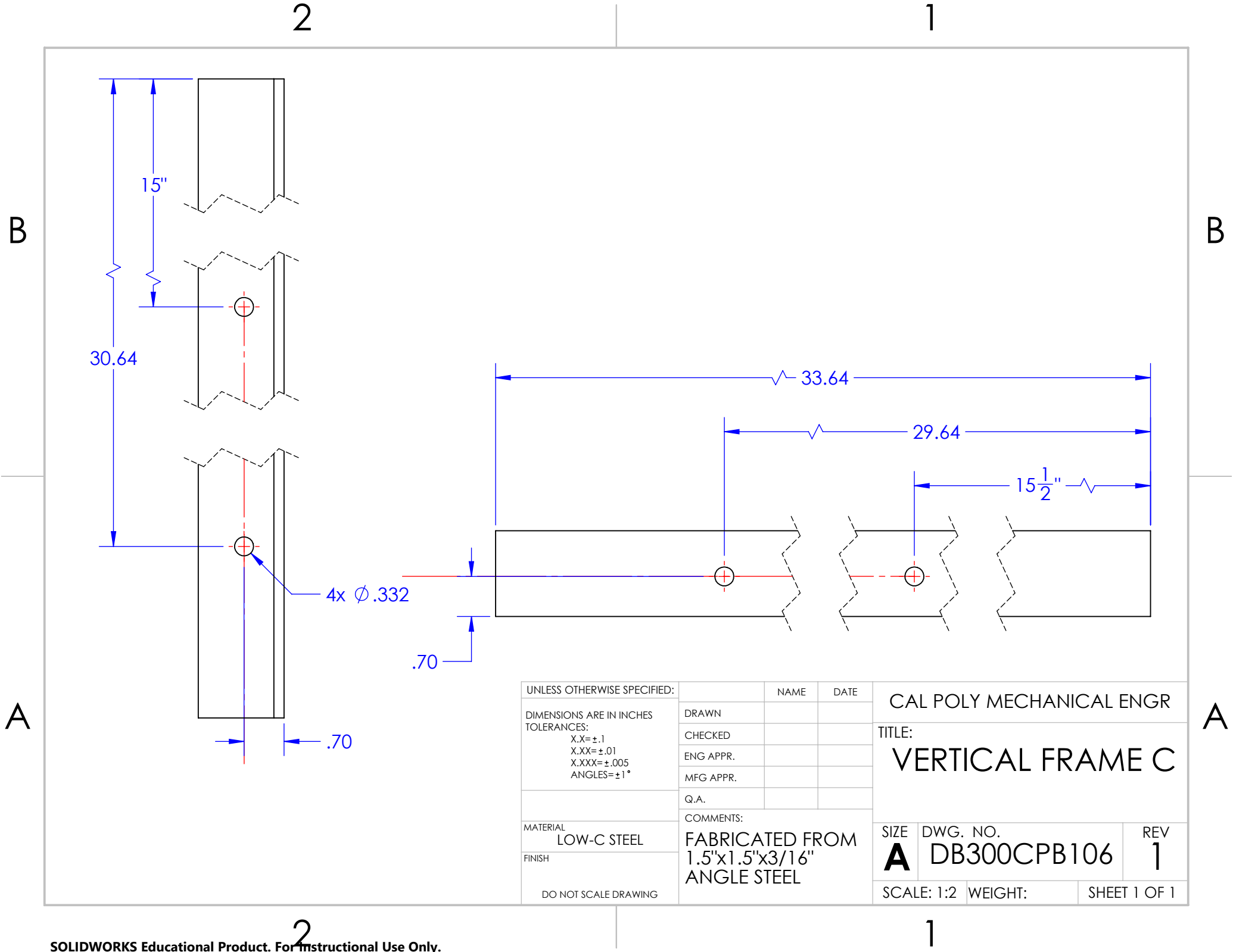




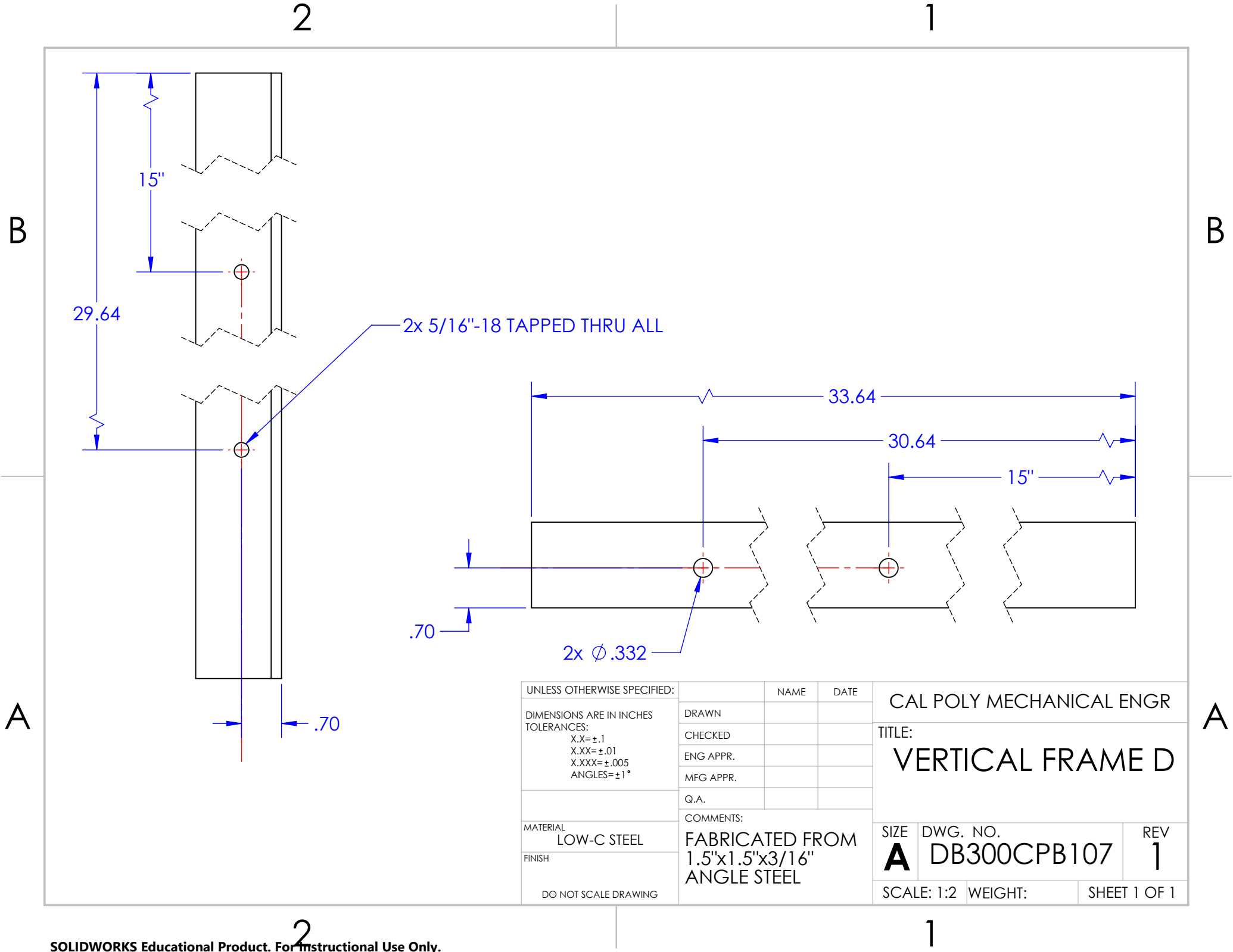
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	MFG APPR.				
	Q.A.			SIZE A	
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		MFG APPR.					
		Q.A.					
MATERIAL		COMMENTS:		SIZE		DWG. NO.	REV
LOW-C STEEL				A		DB300CPB106	1
FINISH				SCALE: 1:2		WEIGHT:	SHEET 1 OF 1
DO NOT SCALE DRAWING							



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
X.X=±.1
X.XX=±.01
X.XXX=±.005
ANGLES=±1°

MATERIAL
LOW-C STEEL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

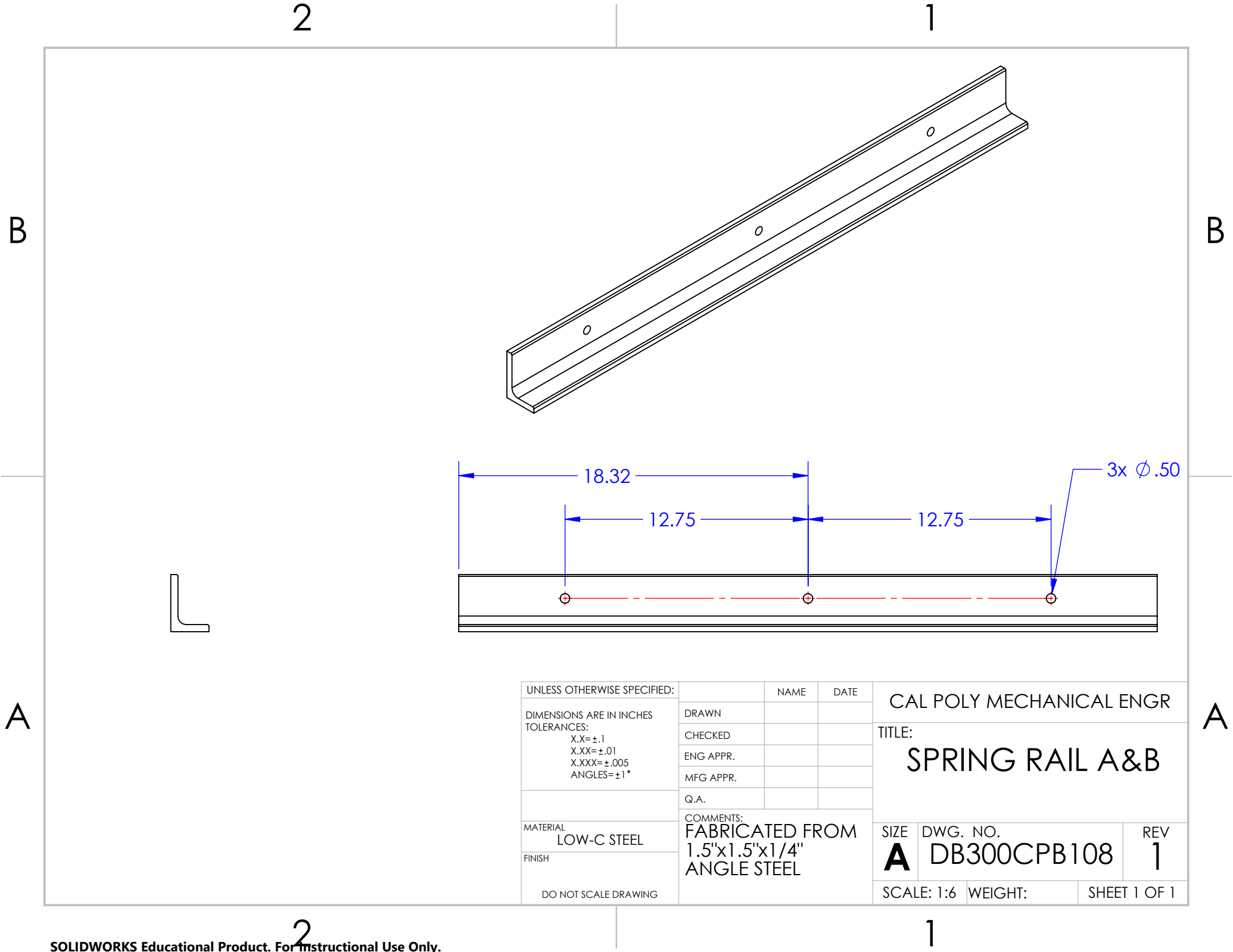
FABRICATED FROM
1.5"x1.5"x3/16"
ANGLE STEEL

CAL POLY MECHANICAL ENGR

TITLE:

VERTICAL FRAME D

SIZE	DWG. NO.	REV
A	DB300CPB107	1
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:

X.X=±.1
X.XX=±.01
X.XXX=±.005
ANGLES=±1°

MATERIAL
LOW-C STEEL

FINISH

DO NOT SCALE DRAWING

DRAWN

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:
FABRICATED FROM
1.5"x1.5"x1/4"
ANGLE STEEL

NAME

DATE

CAL POLY MECHANICAL ENGR

TITLE:

SPRING RAIL A&B

SIZE

A

DWG. NO.

DB300CPB108

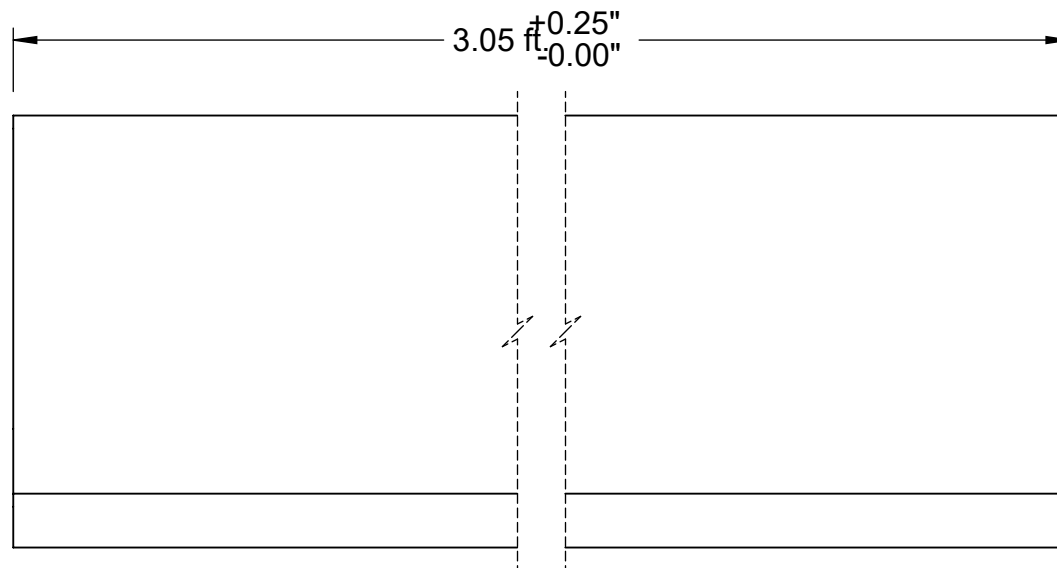
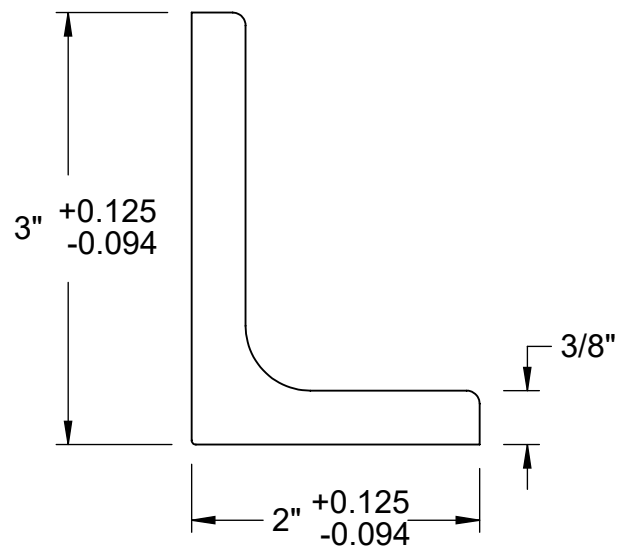
REV

1

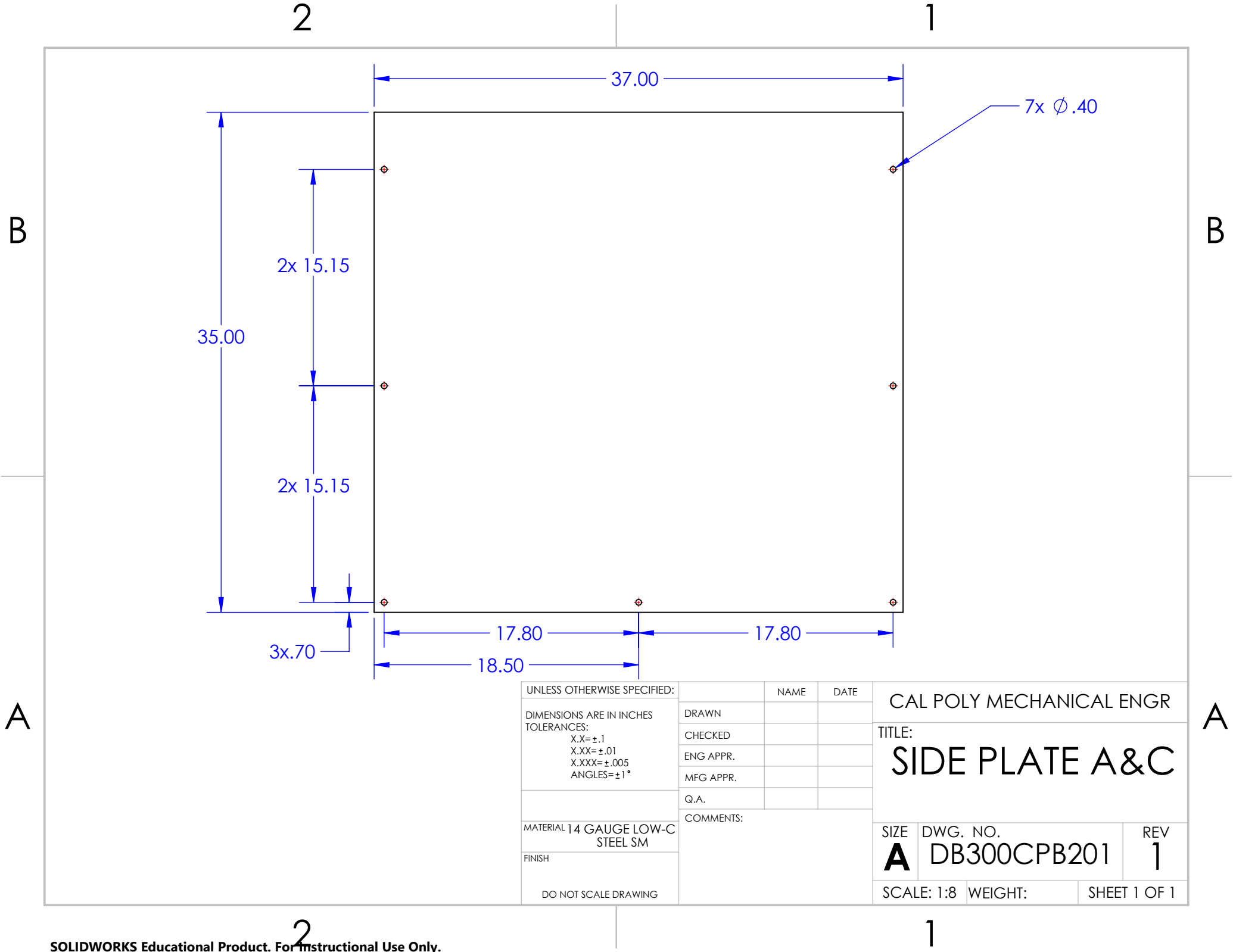
SCALE: 1:6

WEIGHT:

SHEET 1 OF 1



McMASTER-CARR <small>CAD</small> http://www.mcmaster.com © 2019 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	PART NUMBER 9017K871
	Low-Carbon Steel 90° Angle



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:

X.X=±.1
X.XX=±.01
X.XXX=±.005
ANGLES=±1°

MATERIAL 14 GAUGE LOW-C
STEEL SM

FINISH

DO NOT SCALE DRAWING

DRAWN

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:

NAME

DATE

CAL POLY MECHANICAL ENGR

TITLE:

SIDE PLATE A&C

SIZE

A

DWG. NO.

DB300CPB201

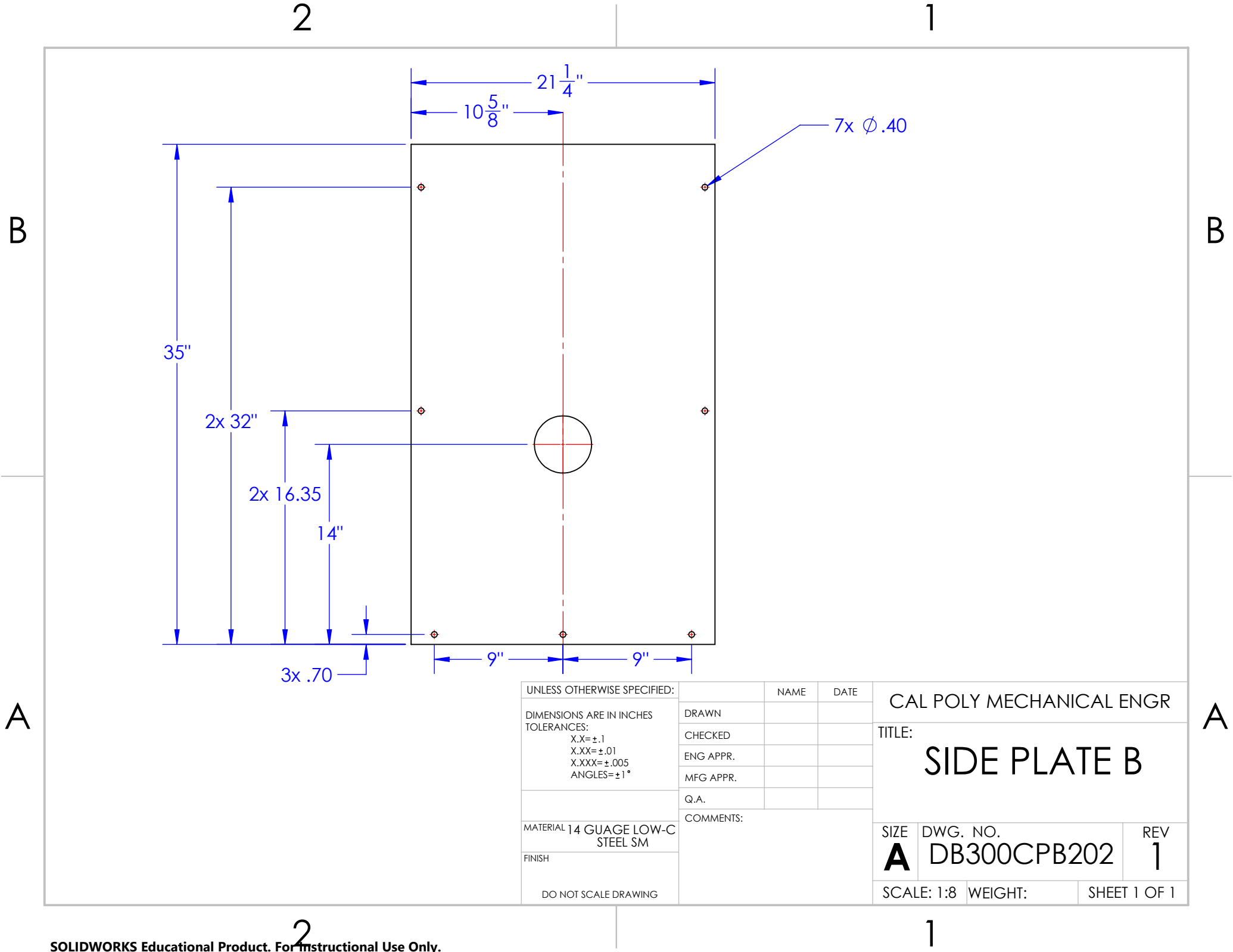
REV

1

SCALE: 1:8

WEIGHT:

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:

X.X=±.1
X.XX=±.01
X.XXX=±.005
ANGLES=±1°

MATERIAL 14 GAUGE LOW-C
STEEL SM

FINISH

DO NOT SCALE DRAWING

DRAWN

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:

NAME

DATE

CAL POLY MECHANICAL ENGR

TITLE:

SIDE PLATE B

SIZE

A

DWG. NO.

DB300CPB202

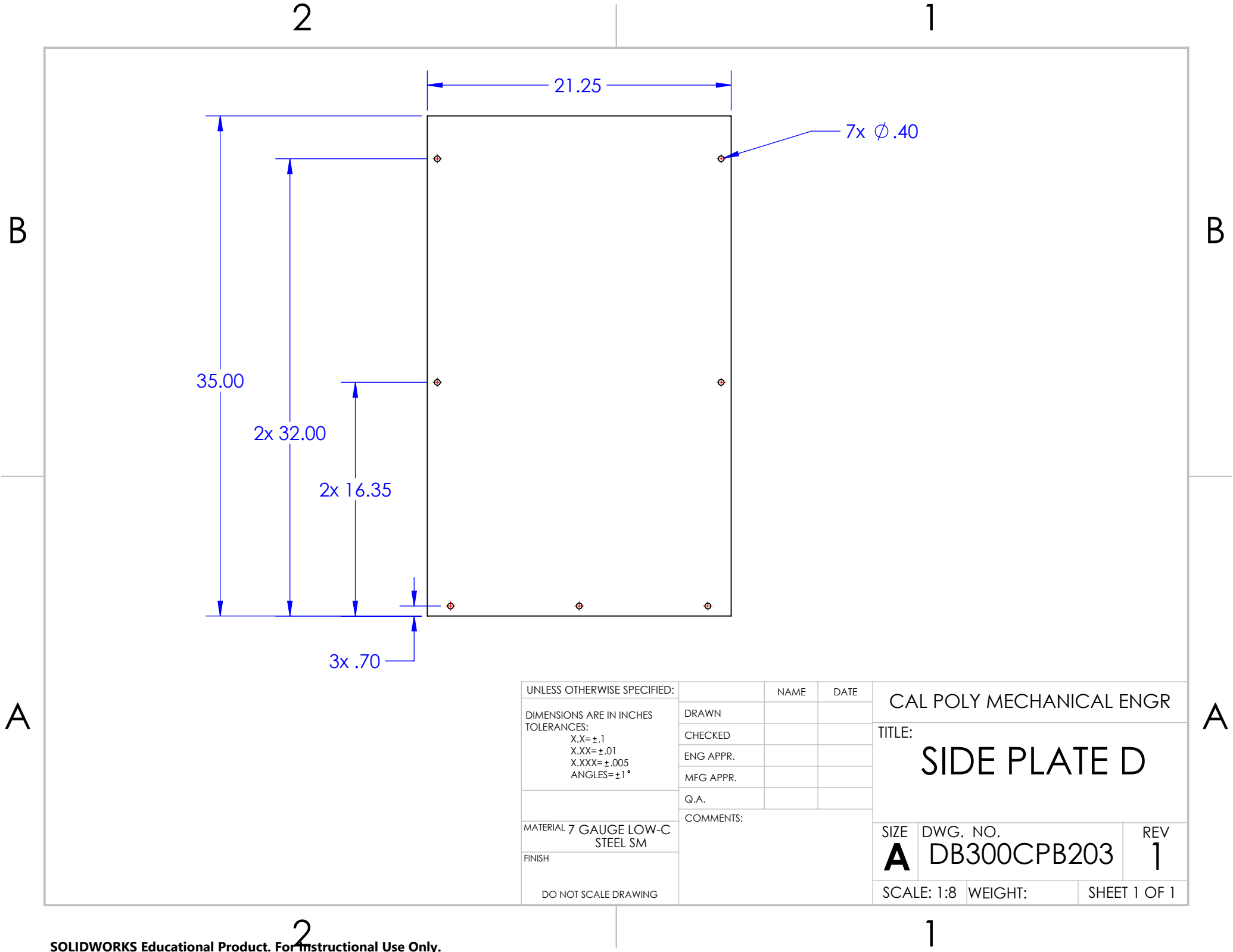
REV

1

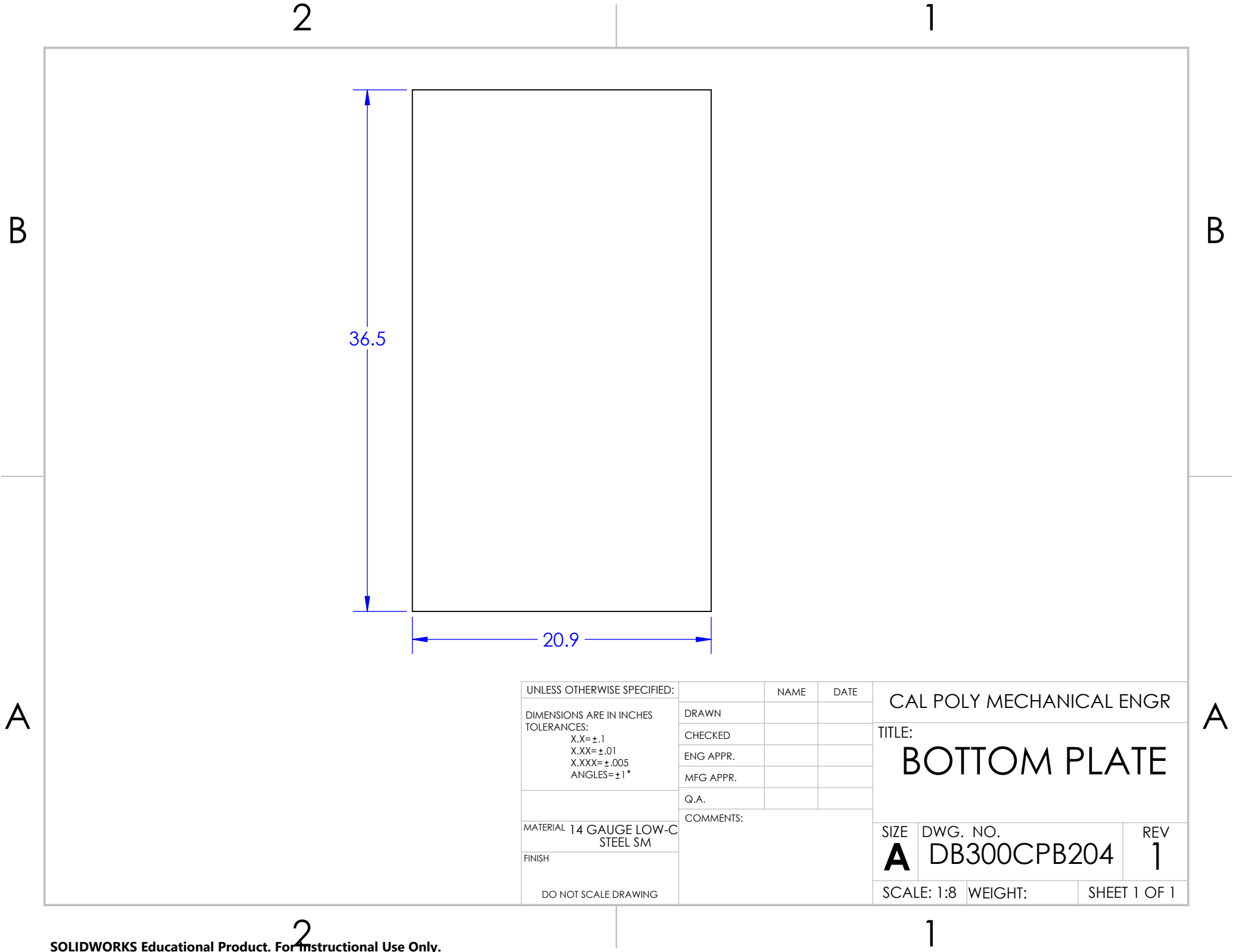
SCALE: 1:8

WEIGHT:

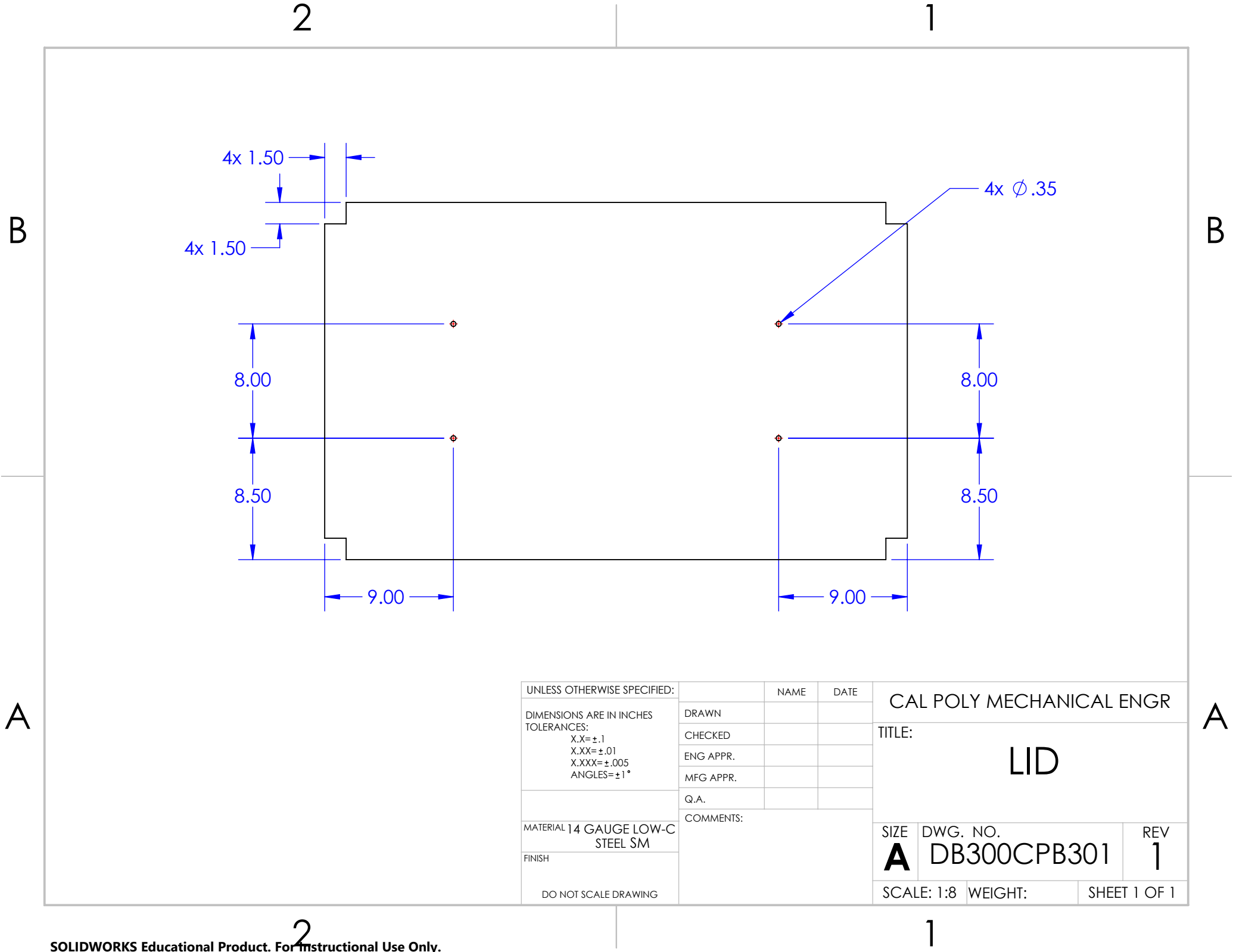
SHEET 1 OF 1

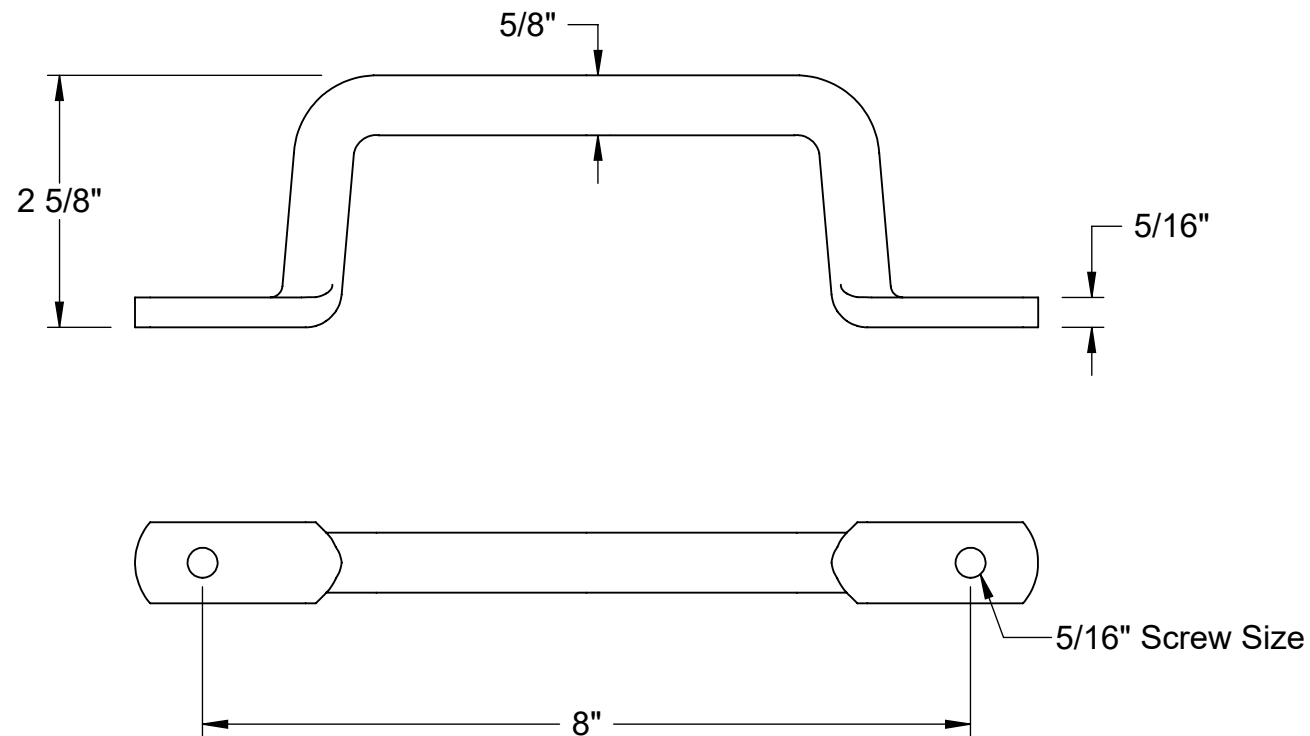
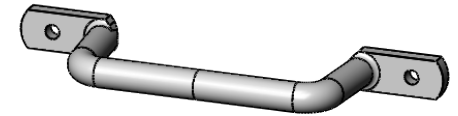


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	CAL POLY MECHANICAL ENGR		
DIMENSIONS ARE IN INCHES TOLERANCES: X.X=±.1 X.XX=±.01 X.XXX=±.005 ANGLES=±1°		DRAWN		TITLE: SIDE PLATE D		
		CHECKED				
		ENG APPR.				
		MFG APPR.				
		Q.A.		SIZE DWG. NO. REV A DB300CPB203 1		
MATERIAL 7 GAUGE LOW-C STEEL SM		COMMENTS:				
FINISH						
DO NOT SCALE DRAWING				SCALE: 1:8	WEIGHT:	SHEET 1 OF 1



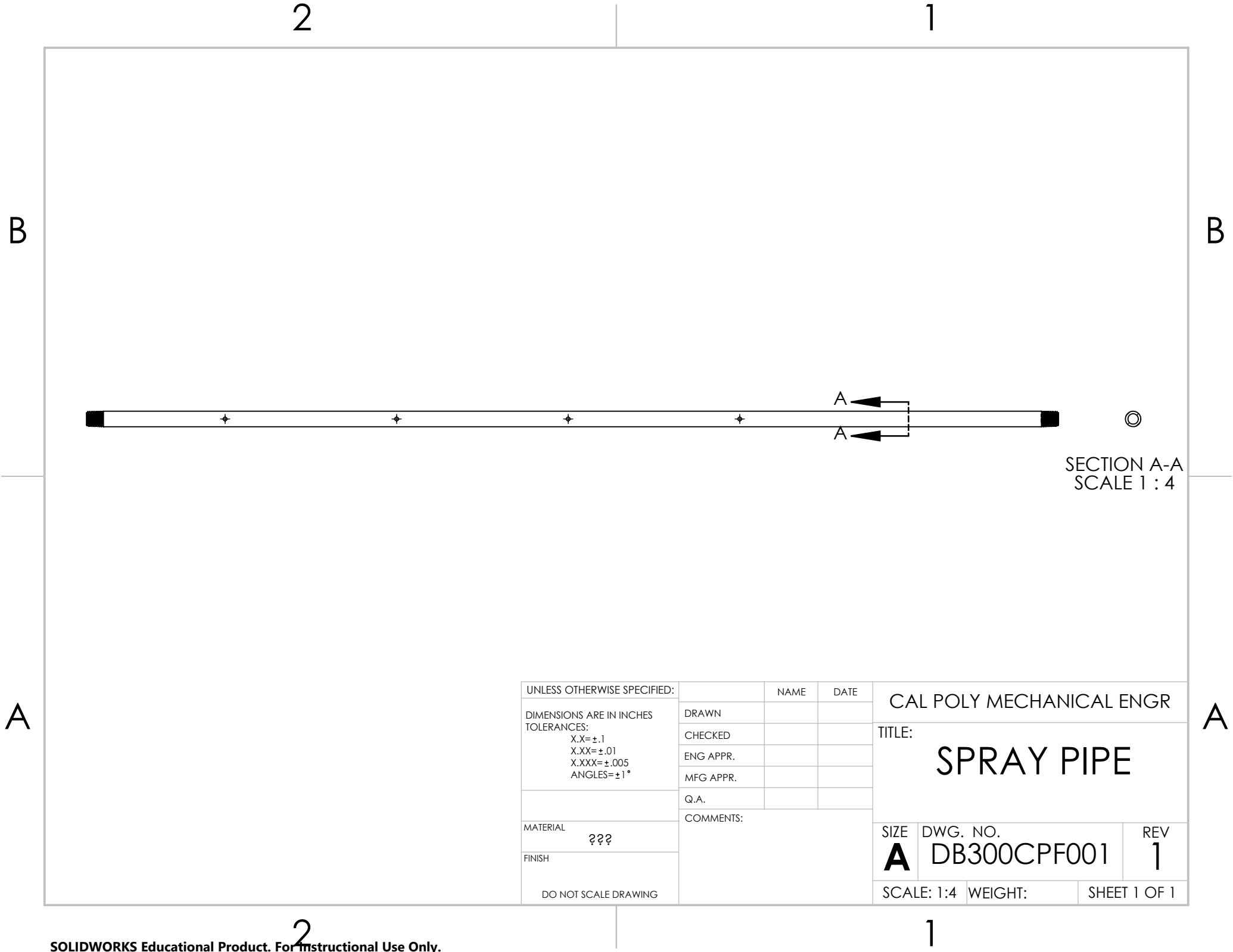
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	CAL POLY MECHANICAL ENGR		
DIMENSIONS ARE IN INCHES TOLERANCES: X.X=±.1 X.XX=±.01 X.XXX=±.005 ANGLES=±1°	DRAWN			TITLE: BOTTOM PLATE		
	CHECKED					
	ENG APPR.					
	MFG APPR.					
	Q.A.			SIZE DWG. NO. REV A DB300CPB204 1		
MATERIAL 14 GAUGE LOW-C STEEL SM	COMMENTS:					
FINISH						
DO NOT SCALE DRAWING		SCALE: 1:8		WEIGHT:	SHEET 1 OF 1	



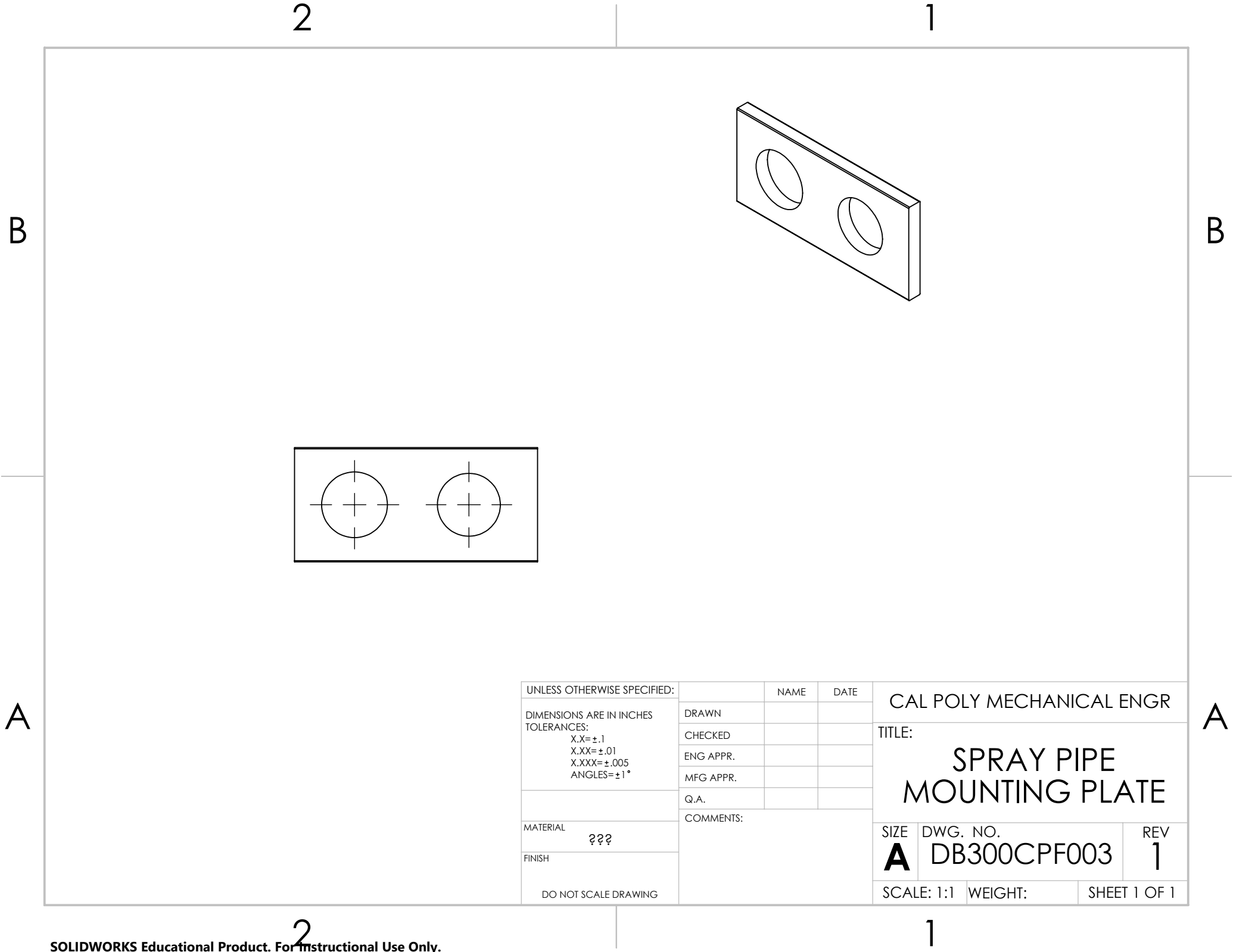


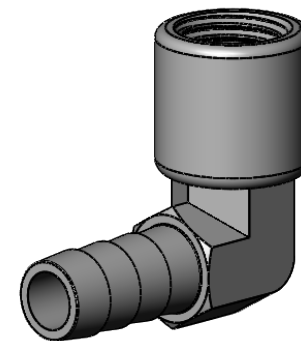
Mounting screws not included.

McMASTER-CARR <small>CAD</small> http://www.mcmaster.com © 2012 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	PART NUMBER 5186A5
	Dull Finish Type 304 Stainless Steel Formed Pull Handle

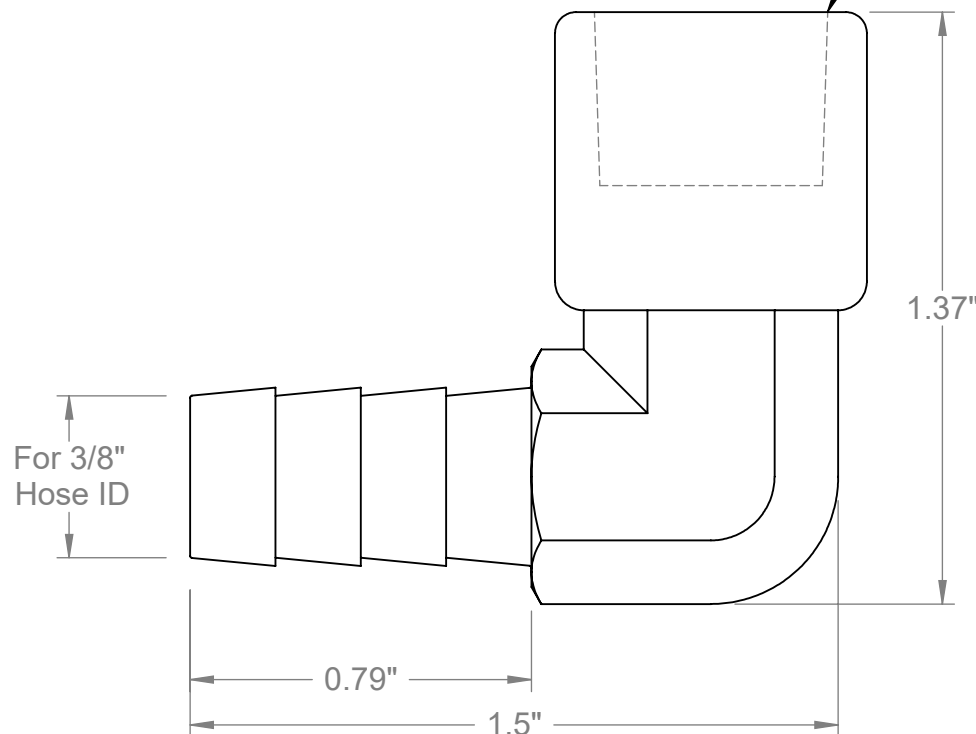
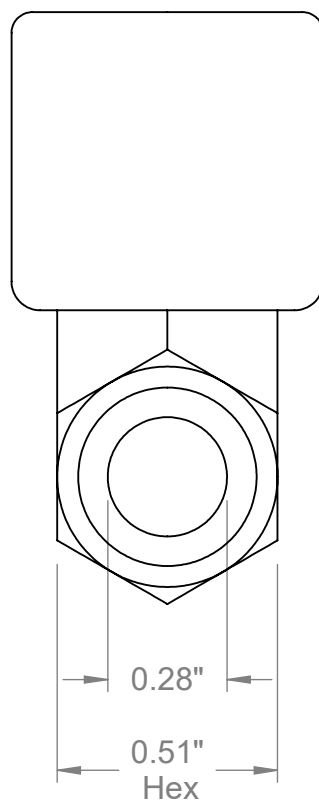


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	CAL POLY MECHANICAL ENGR	
DIMENSIONS ARE IN INCHES TOLERANCES: X.X=±.1 X.XX=±.01 X.XXX=±.005 ANGLES=±1°		DRAWN		TITLE: SPRAY PIPE	
		CHECKED			
		ENG APPR.			
		MFG APPR.			
		Q.A.			
		COMMENTS:			
MATERIAL	???			SIZE	DWG. NO.
FINISH				A	DB300CPF001
DO NOT SCALE DRAWING				SCALE: 1:4	REV
				WEIGHT:	1
				SHEET 1 OF 1	





1/4 NPTF Pipe Size, 18 Threads Per Inch,
0.40" Thread Engagement



McMASTER-CARR CAD

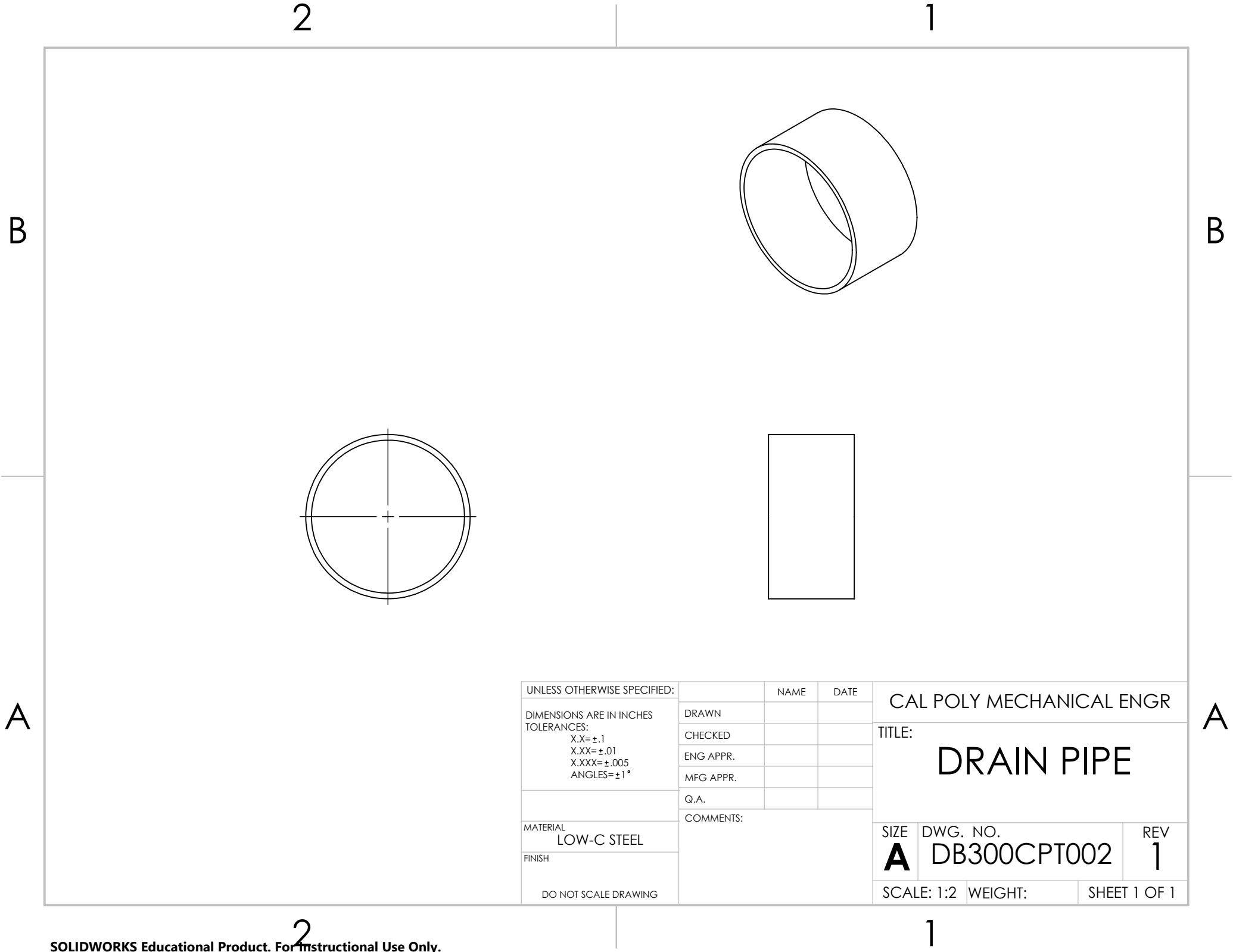
<http://www.mcmaster.com>
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Information in this drawing is provided for reference only.

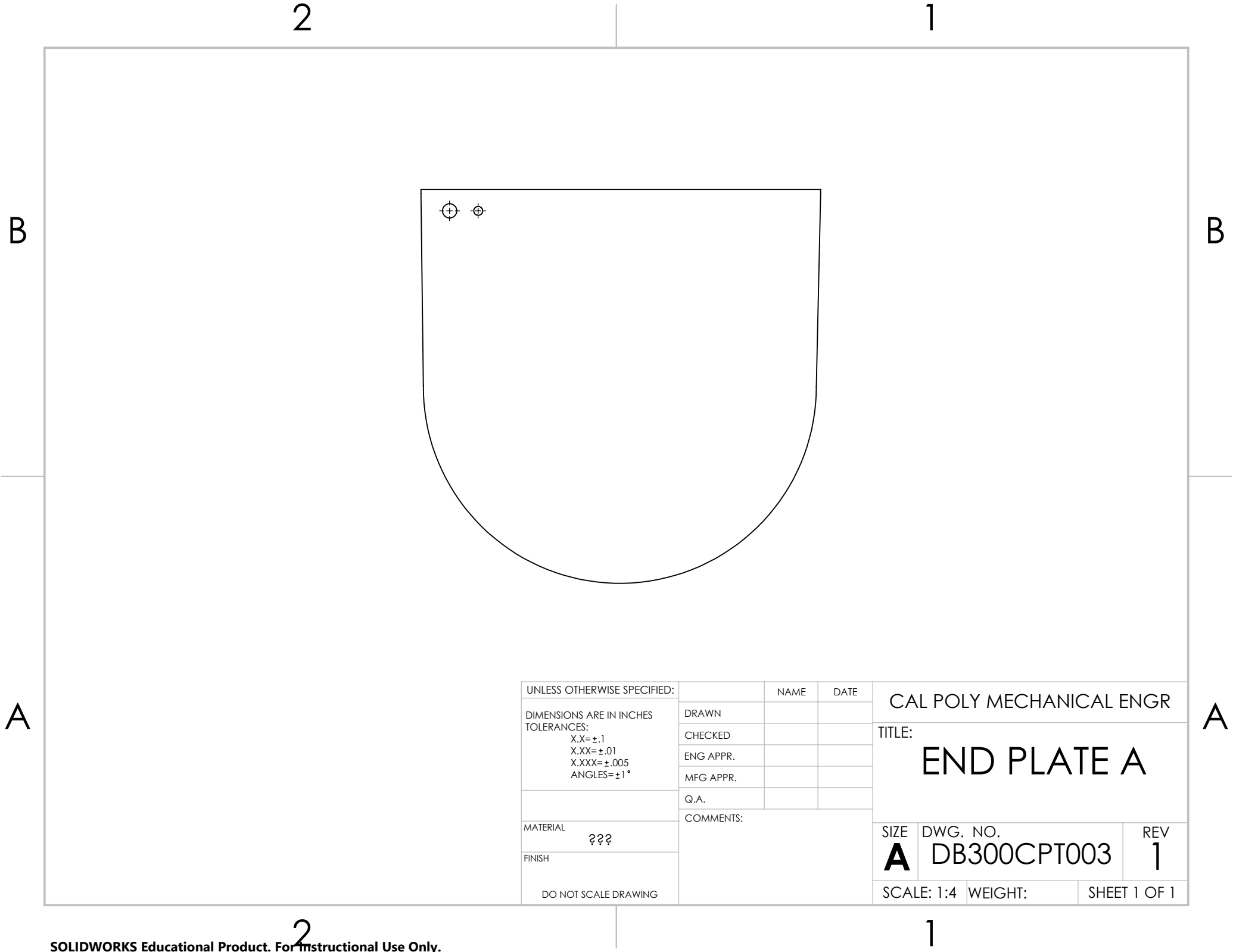
PART
NUMBER

5346K123

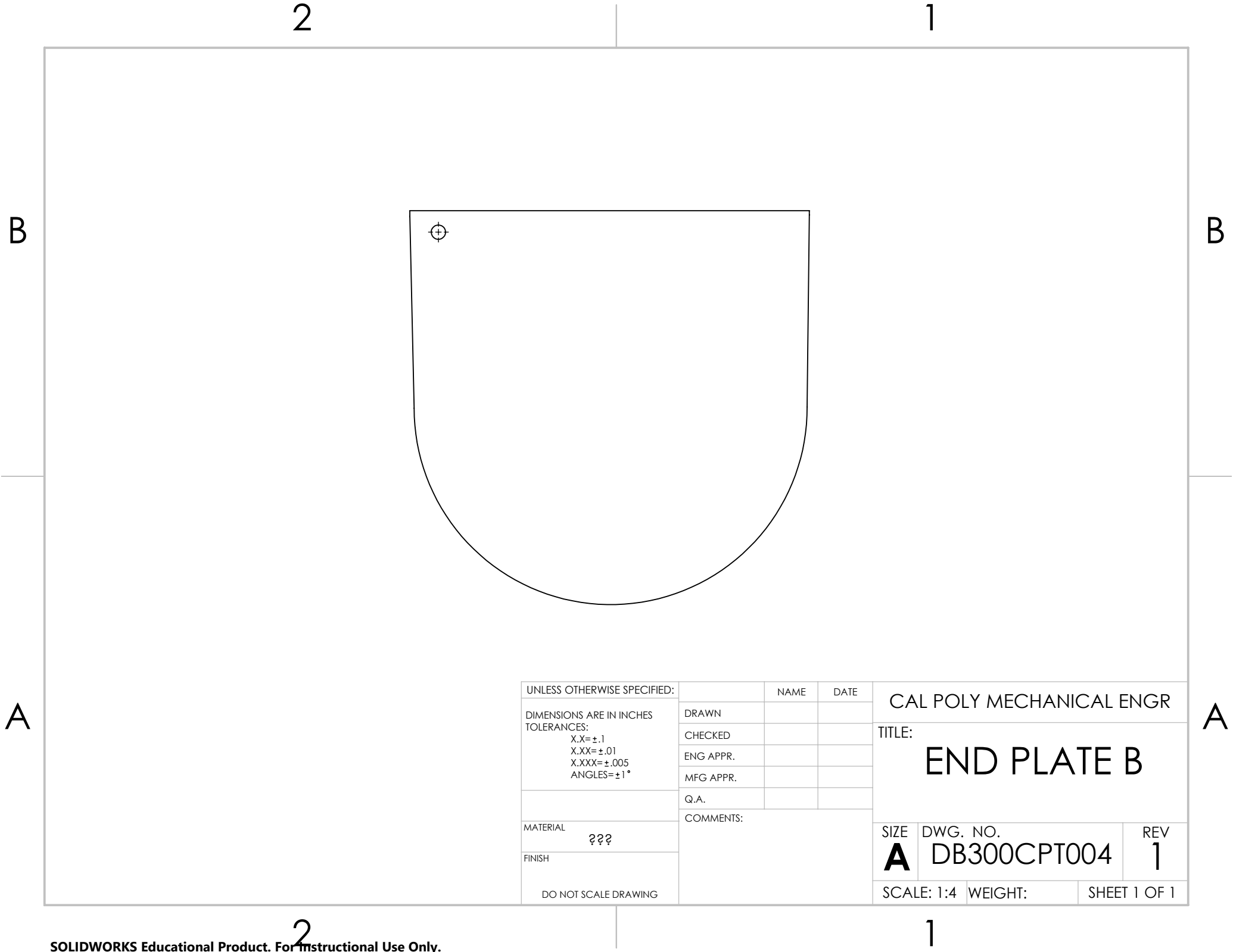
Brass Barbed Hose
Female Pipe 90° Elbow



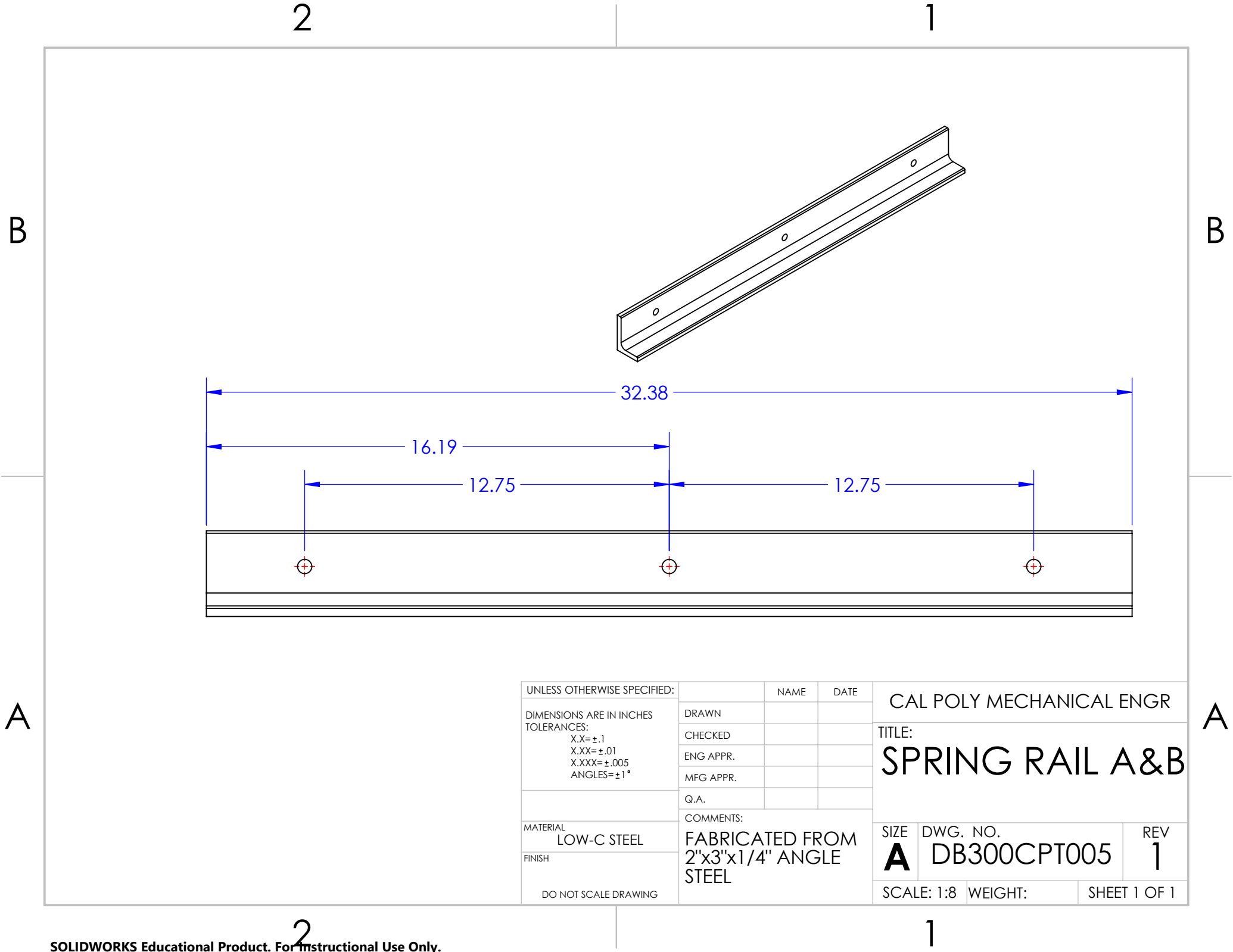
UNLESS OTHERWISE SPECIFIED:		NAME		DATE		CAL POLY MECHANICAL ENGR			
DIMENSIONS ARE IN INCHES TOLERANCES: X.X=±.1 X.XX=±.01 X.XXX=±.005 ANGLES=±1°		DRAWN				TITLE: DRAIN PIPE			
		CHECKED							
		ENG APPR.							
		MFG APPR.							
		Q.A.				SIZE DWG. NO. REV DB300CPT002 1			
MATERIAL LOW-C STEEL		COMMENTS:							
FINISH									
DO NOT SCALE DRAWING				SCALE: 1:2		WEIGHT:		SHEET 1 OF 1	



UNLESS OTHERWISE SPECIFIED:		NAME		DATE		CAL POLY MECHANICAL ENGR					
DIMENSIONS ARE IN INCHES TOLERANCES: X.X=±.1 X.XX=±.01 X.XXX=±.005 ANGLES=±1°		DRAWN				TITLE: END PLATE A					
		CHECKED									
		ENG APPR.									
		MFG APPR.									
		Q.A.									
MATERIAL		COMMENTS:				SIZE		DWG. NO.		REV	
FINISH						A		DB300CPT003		1	
DO NOT SCALE DRAWING						SCALE: 1:4		WEIGHT:		SHEET 1 OF 1	



UNLESS OTHERWISE SPECIFIED:			NAME	DATE	CAL POLY MECHANICAL ENGR					
DIMENSIONS ARE IN INCHES TOLERANCES: X.X=±.1 X.XX=±.01 X.XXX=±.005 ANGLES=±1°		DRAWN			TITLE: END PLATE B					
		CHECKED								
		ENG APPR.								
		MFG APPR.								
		Q.A.			SIZE A					
MATERIAL ???		COMMENTS:						DWG. NO. DB300CPT004		REV 1
FINISH								SCALE: 1:4		WEIGHT:
DO NOT SCALE DRAWING										



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:

X.X=±.1
X.XX=±.01
X.XXX=±.005
ANGLES=±1°

MATERIAL
LOW-C STEEL

FINISH

DO NOT SCALE DRAWING

DRAWN

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:

FABRICATED FROM
2"x3"x1/4" ANGLE
STEEL

NAME

DATE

CAL POLY MECHANICAL ENGR

TITLE:

SPRING RAIL A&B

SIZE

A

DWG. NO.

DB300CPT005

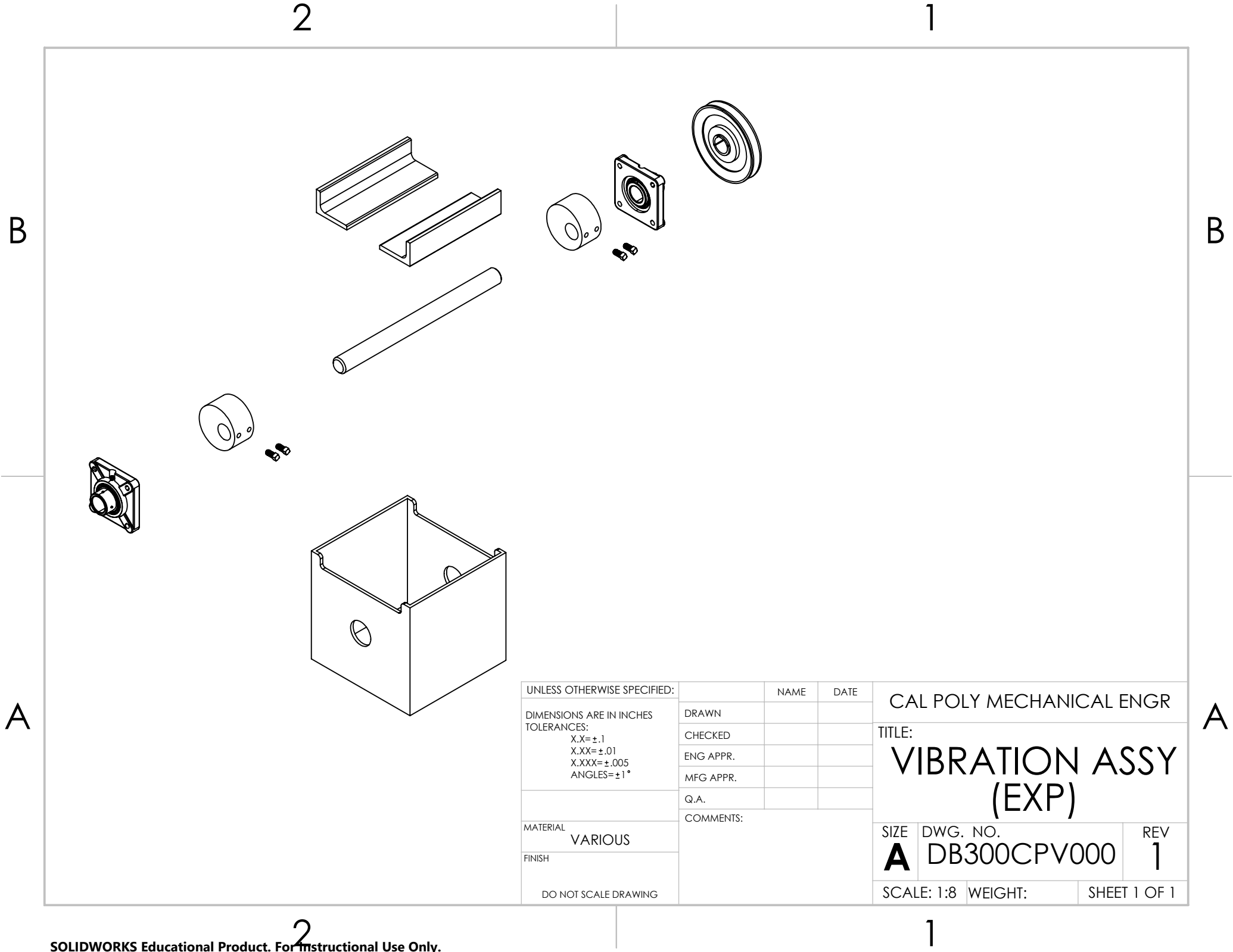
REV

1

SCALE: 1:8

WEIGHT:

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
X.X=±.1
X.XX=±.01
X.XXX=±.005
ANGLES=±1°

MATERIAL VARIOUS

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

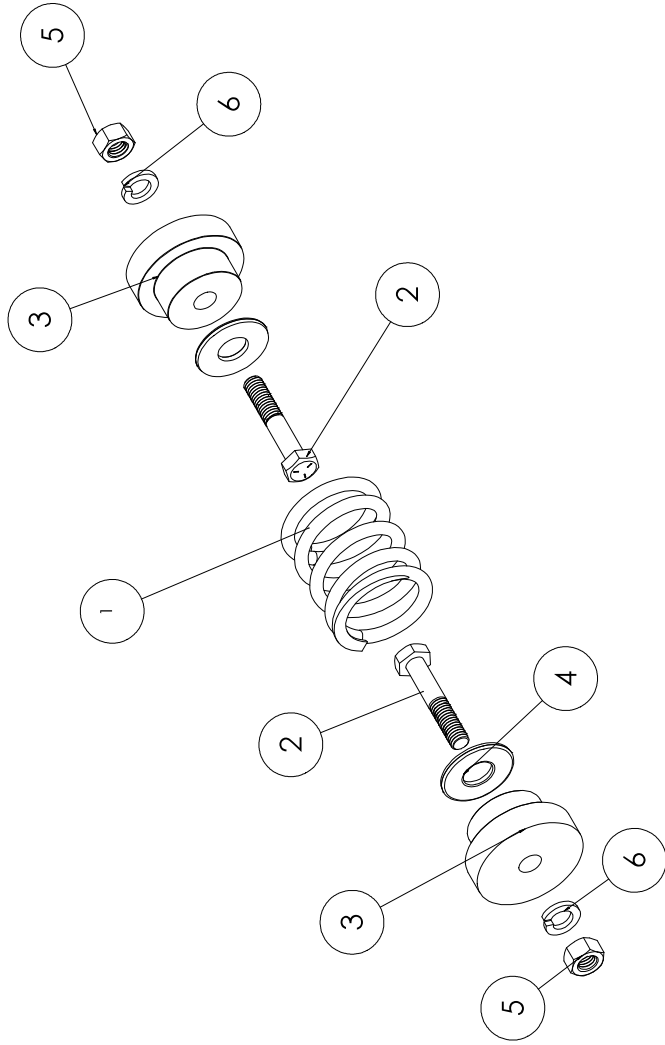
CAL POLY MECHANICAL ENGR

TITLE:
**VIBRATION ASSY
(EXP)**

SIZE	DWG. NO.	REV
A	DB300CPV000	1

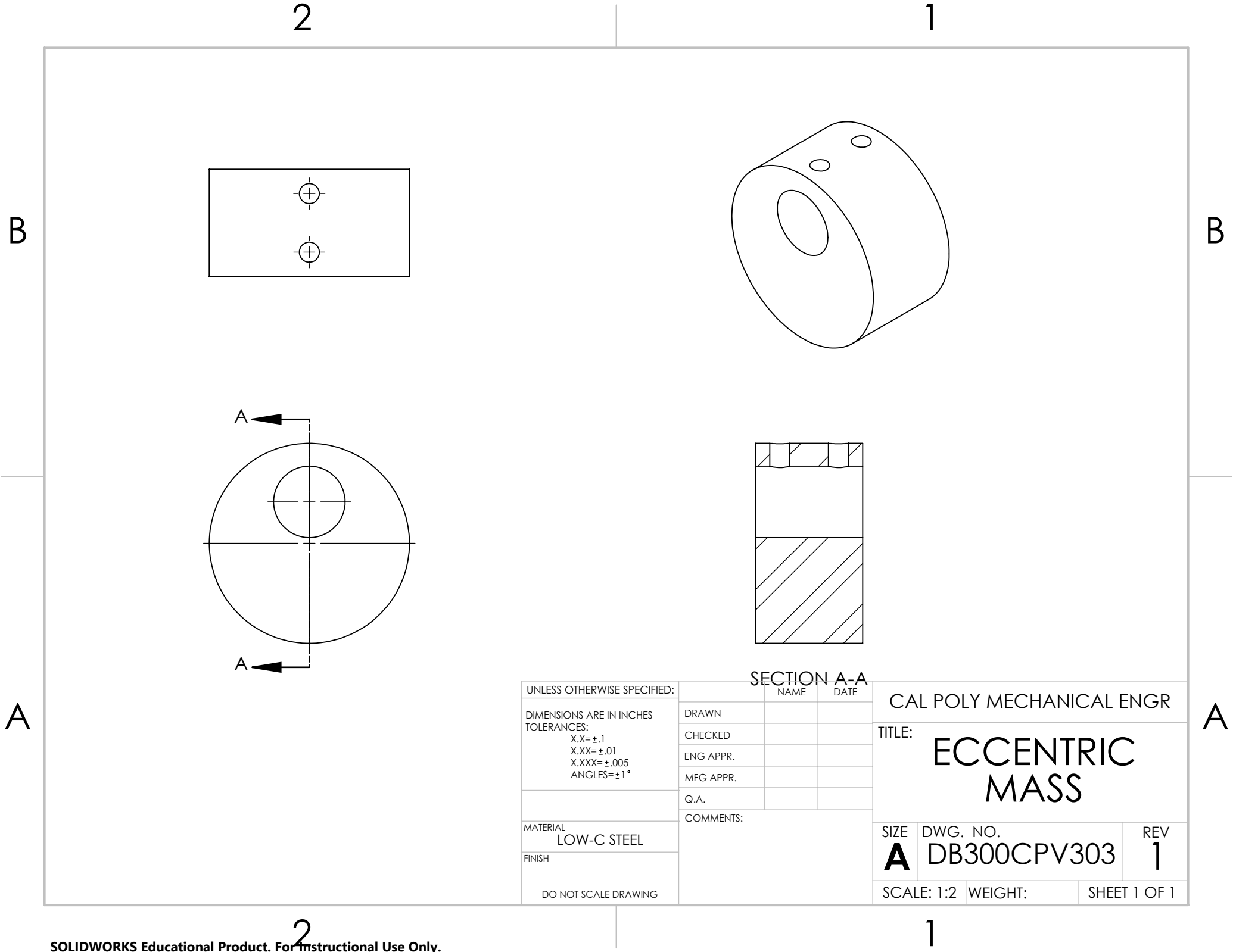
SCALE: 1:8	WEIGHT:	SHEET 1 OF 1
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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	DB300D801	Flat End Spring	1
2	DB300D802	Hex Screw Partially Threaded 7/16 13	2
3	DB300D803	Spring Plastic Holder	2
4	DB300D804	Spring Washer 1.75 OD	2
5	DB300D001	Hex Nut 1/2 13	2
6	DB300D002	Split Lock Washer	2



C & M TOPLINE
 5945 Daley Street
 Goleta CA 93117
 1 800 827-1333
www.candmtopline.com

PART NO.	DB300D800
DESCRIPTION	Mr Debur Spring Assembly
QTY.	



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
X.X=±.1
X.XX=±.01
X.XXX=±.005
ANGLES=±1°

MATERIAL
LOW-C STEEL

FINISH

DO NOT SCALE DRAWING

SECTION A-A

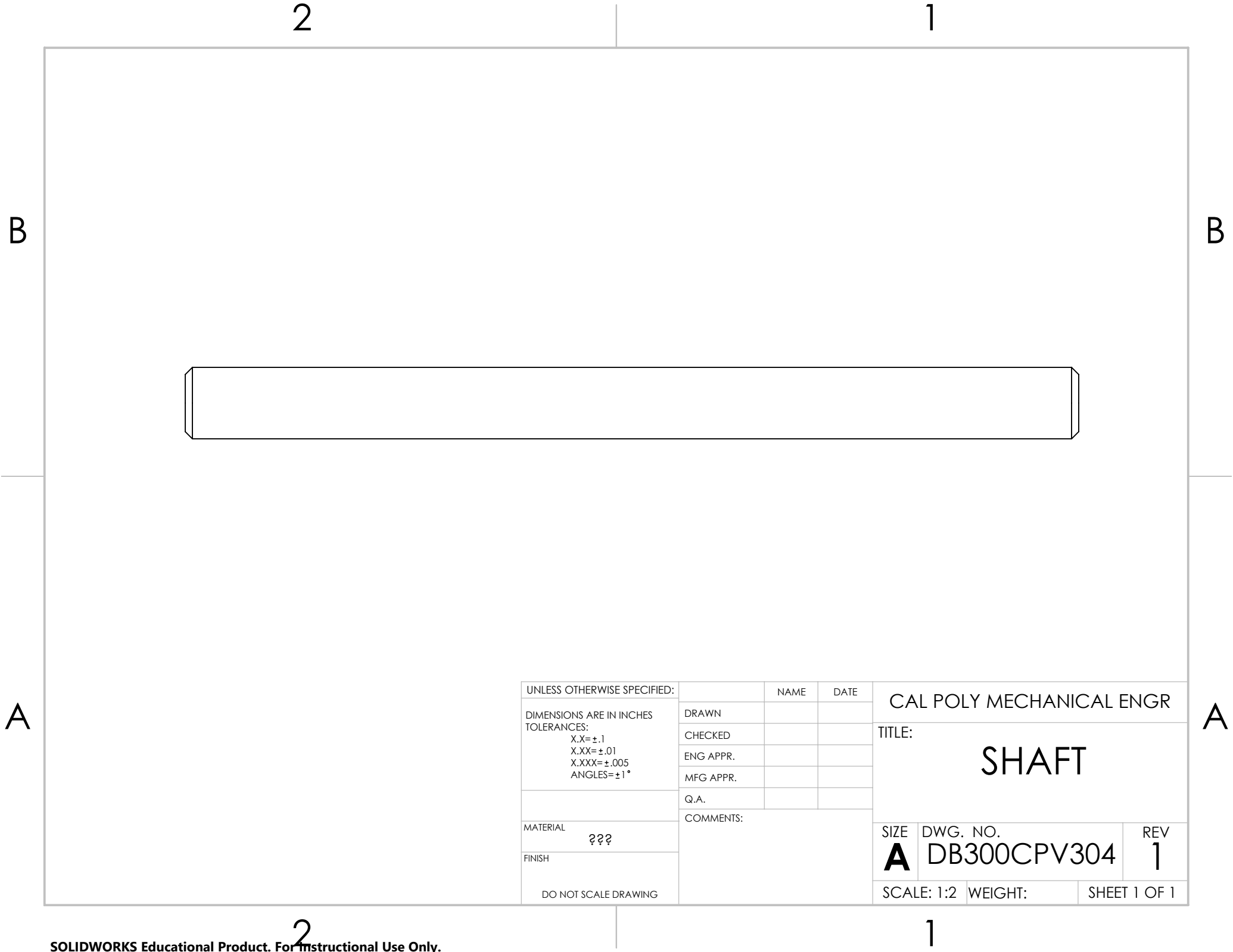
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DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

CAL POLY MECHANICAL ENGR

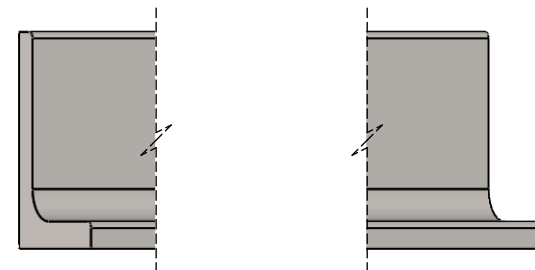
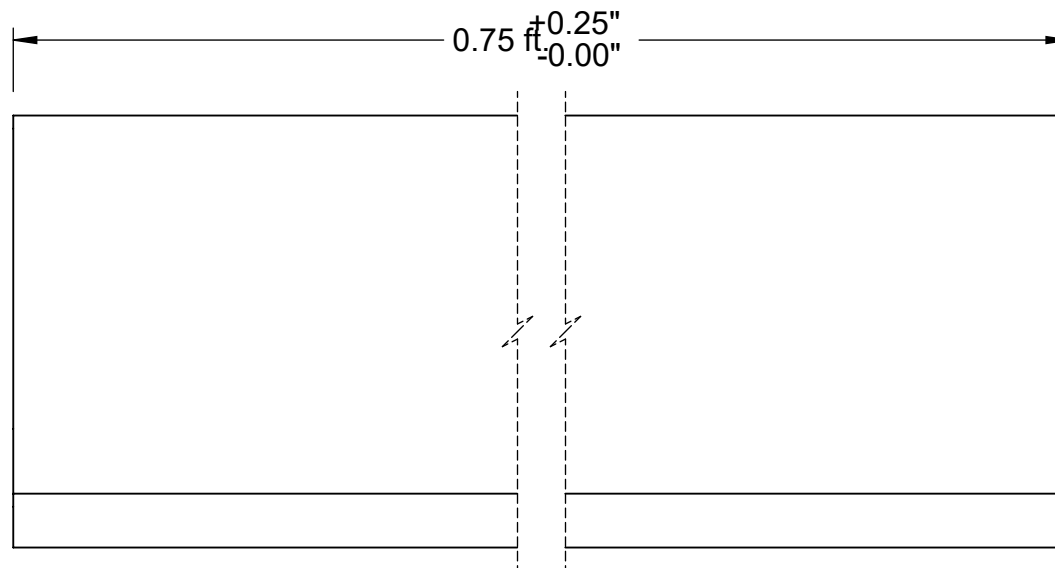
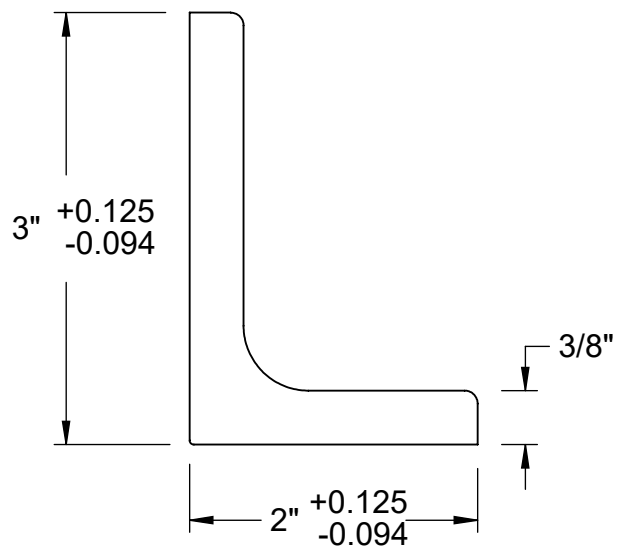
TITLE:
**ECCENTRIC
MASS**

SIZE	DWG. NO.	REV
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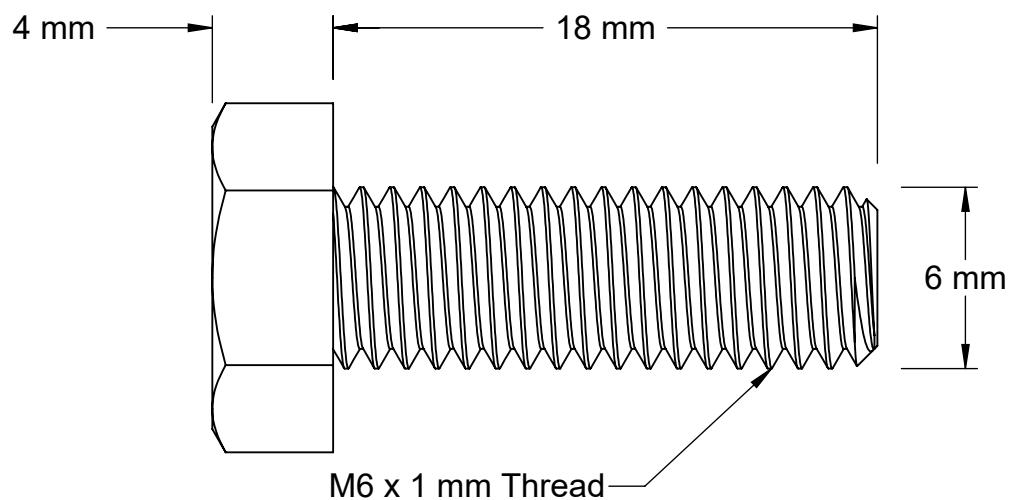
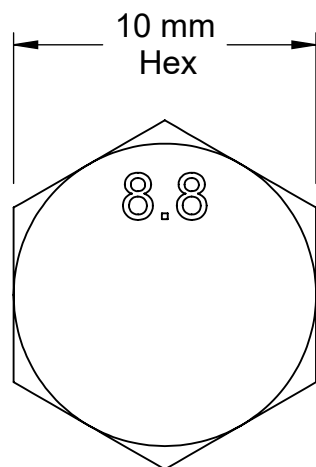
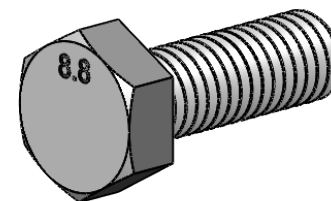
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1
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UNLESS OTHERWISE SPECIFIED:			NAME	DATE	CAL POLY MECHANICAL ENGR					
DIMENSIONS ARE IN INCHES TOLERANCES: X.X=±.1 X.XX=±.01 X.XXX=±.005 ANGLES=±1°		DRAWN			TITLE: SHAFT					
		CHECKED								
		ENG APPR.								
		MFG APPR.								
		Q.A.			SIZE A					
MATERIAL ???		COMMENTS:						DWG. NO. DB300CPV304		REV 1
FINISH								SCALE: 1:2		WEIGHT:
DO NOT SCALE DRAWING										



McMASTER-CARR <small>CAD</small> http://www.mcmaster.com © 2019 McMaster-Carr Supply Company <small>Information in this drawing is provided for reference only.</small>	PART NUMBER 9017K871
	Low-Carbon Steel 90° Angle



McMASTER-CARR CAD

<http://www.mcmaster.com>

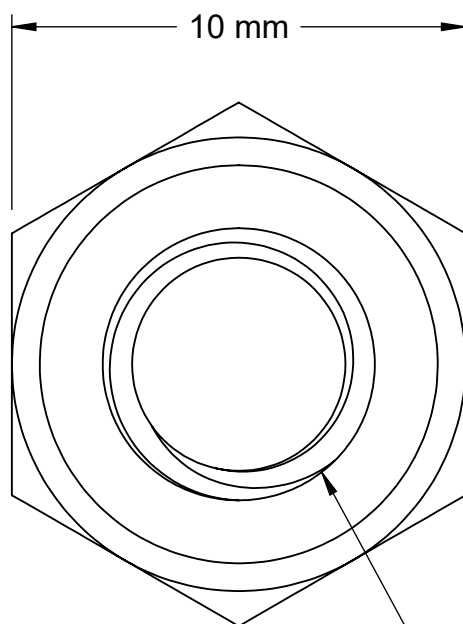
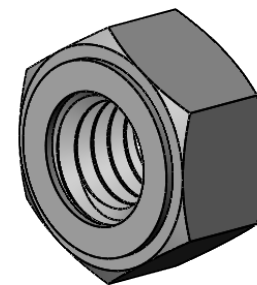
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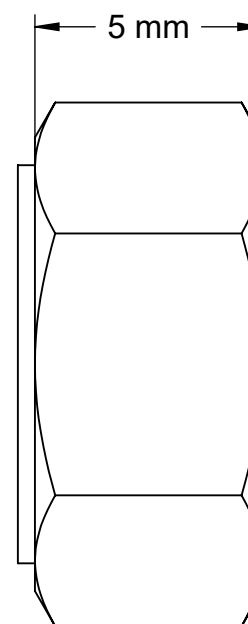
PART
NUMBER

91280A328

Metric Medium-Strength Steel
Cap Screw - Class 8.8



M6 x 1 mm Thread



McMASTER-CARR CAD

<http://www.mcmaster.com>

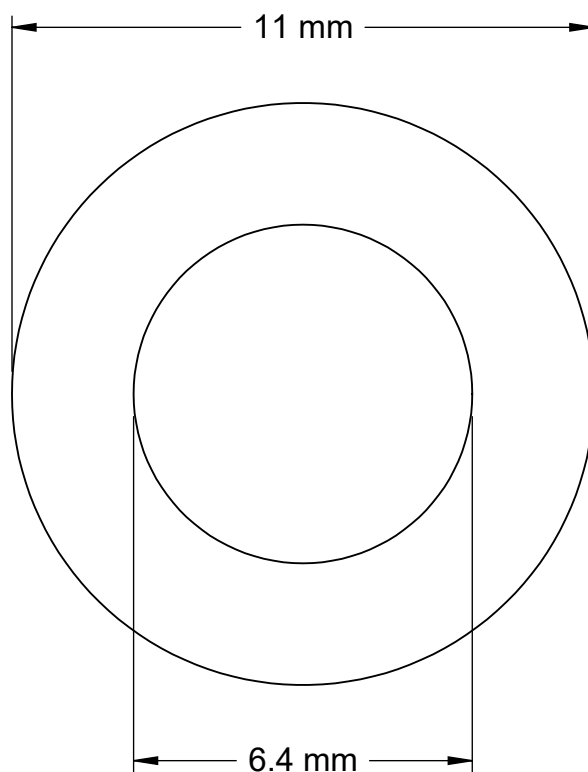
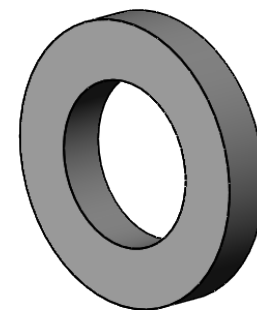
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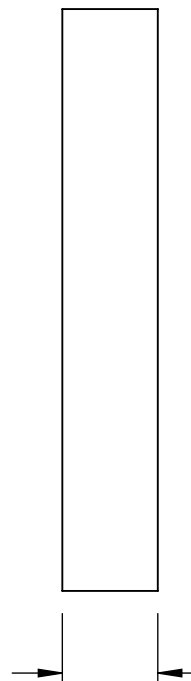
PART
NUMBER

90592A016

Metric Medium-Strength Steel
Hex Nut - Class 8

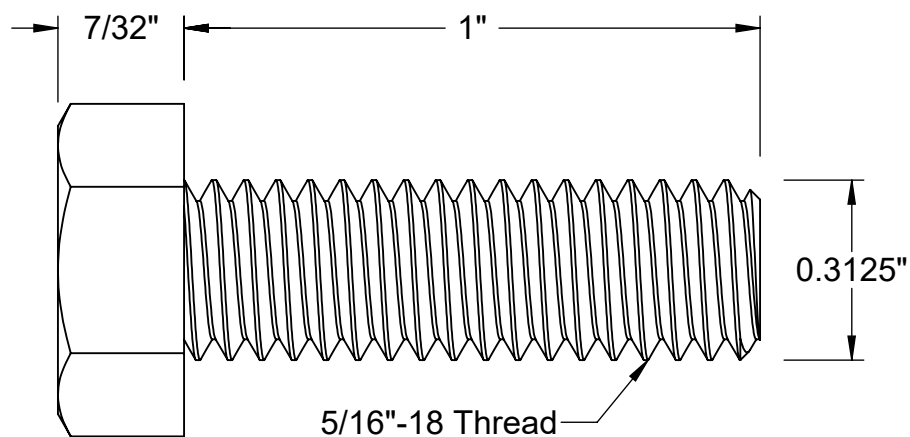
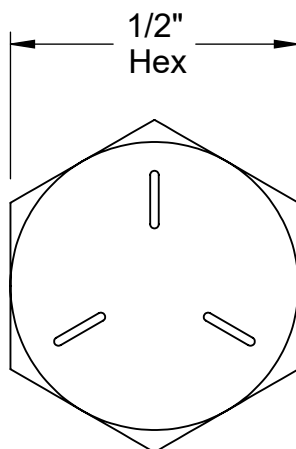
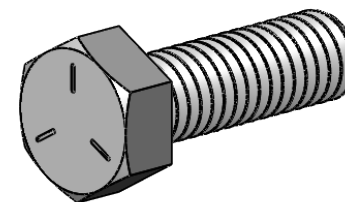


For M6
Screw Size



Washer may vary from
1.4 mm to 1.8 mm in thickness.

McMASTER-CARR <small>CAD</small> http://www.mcmaster.com © 2020 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	PART NUMBER	98689A115
	Metric General Purpose Washer	



McMASTER-CARR CAD

<http://www.mcmaster.com>

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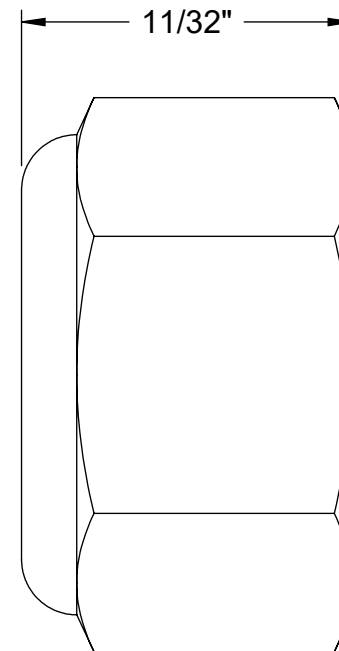
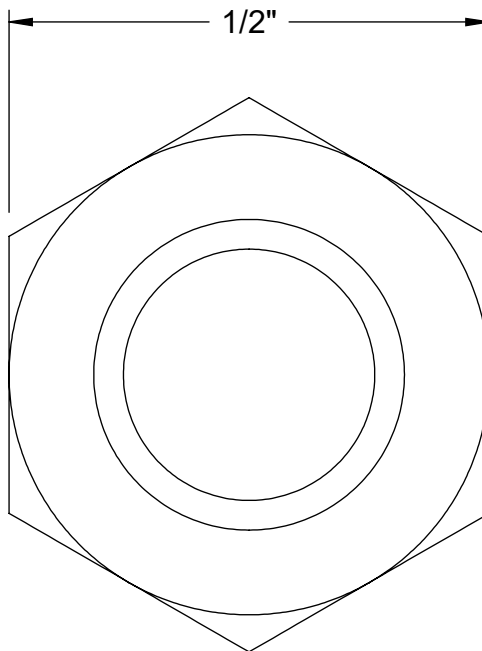
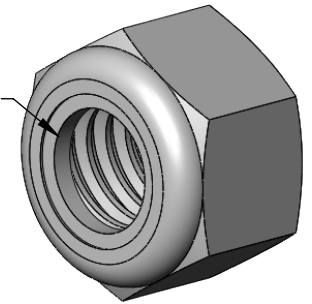
Information in this drawing is provided for reference only.

PART
NUMBER

92865A583

Medium-Strength Steel
Cap Screw - Grade 5

5/16"-18 Thread



McMASTER-CARR CAD

<http://www.mcmaster.com>
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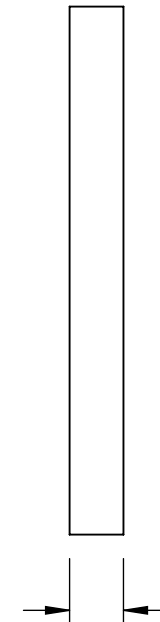
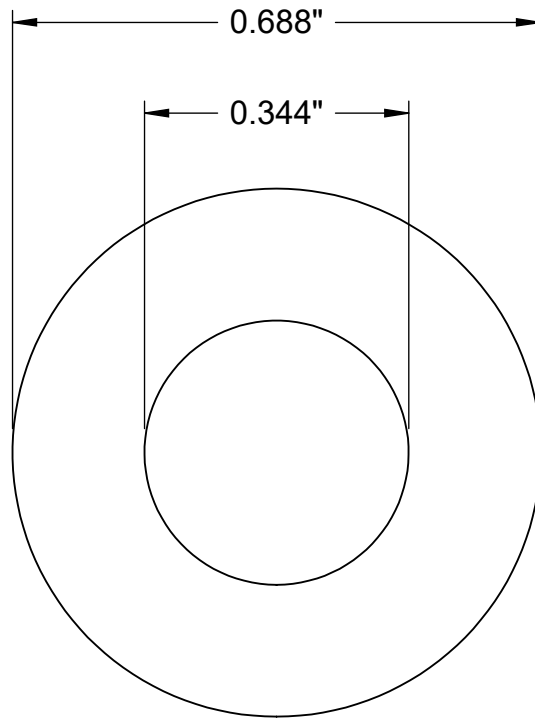
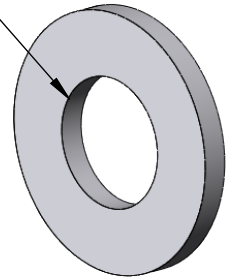
Information in this drawing is provided for reference only.

PART
NUMBER

90640A130

Nylon-Insert
Locknut

For 5/16"
Screw Size



Washer may vary from
0.051" to 0.08" in thickness.

McMASTER-CARR CAD

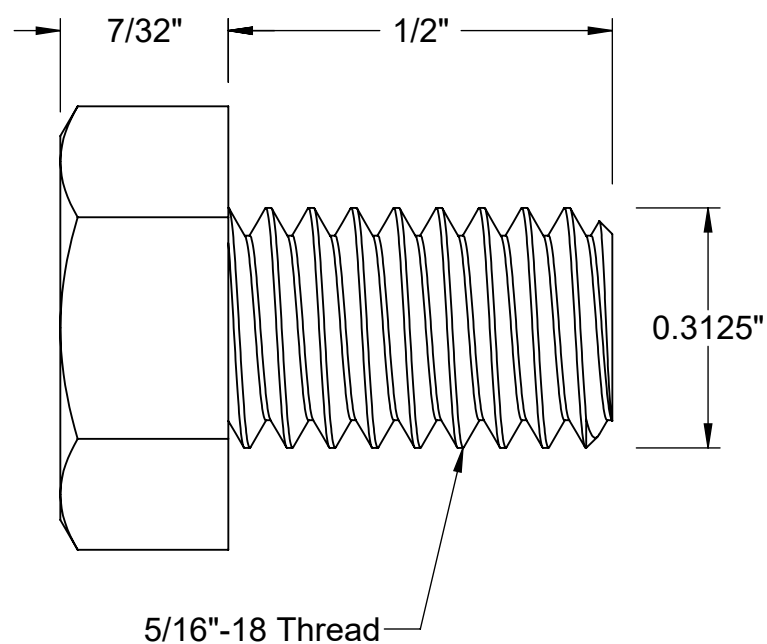
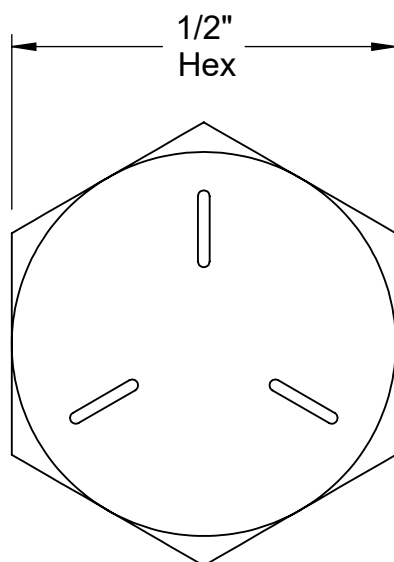
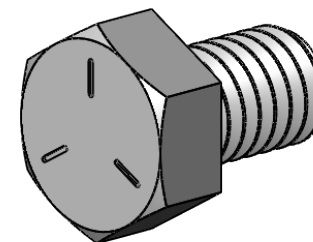
<http://www.mcmaster.com>
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Information in this drawing is provided for reference only.

PART
NUMBER

96659A107

SAE
Washer



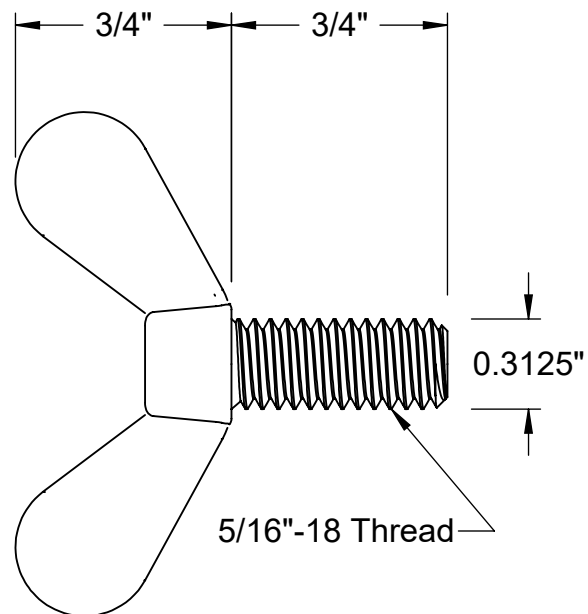
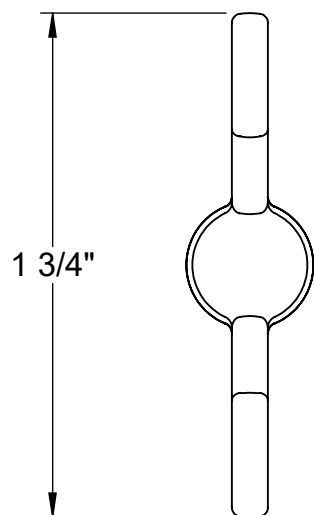
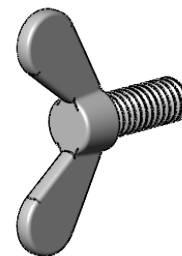
McMASTER-CARR CAD

<http://www.mcmaster.com>
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PART NUMBER **92865A578**

Medium-Strength Steel
Cap Screw - Grade 5



McMASTER-CARR CAD

PART
NUMBER

97568A581

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Wing Head
Thumb Screw